RESEARCH BULLETIN 974 NOVEMBER 1965

Econometric Generalizations of the Ohio Beef and Pork Industries in Interregional Competition

GENE A. FUTRELL

FRANCIS E. WALKER

THOMAS T. STOUT

OHIO AGRICULTURAL RESEARCH AND DEVELOPMENT CENTER
WOOSTER, OHIO

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AGDEX 845/480

11-65-2M

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SUMMARY

Transportation models were employed to obtain optimum shipment patterns for live cattle, calves, and hogs in 1962 from surplus production regions to regions of surplus slaughter. Multiproduct spatial equilibrium solutions provided optimum shipment patterns for carcass beef and pork from surplus slaughter regions to surplus consumption (deficit slaughter) regions. Multiproduct spatial equilibrium solutions also were developed for optimum production-to-consumption shipments of carcass beef and pork, under the assumption that all cattle, calf, and hog slaughter occurred in the region where the livestock were produced.

Eight 29-region models were developed for projected 1975 production, slaughter, and consumption conditions for beef and pork. These included production-to-slaughter transportation models for both cattle and hogs; slaughter-to-consumption multiproduct spatial equilibrium models for both beef and pork; and two sets of production-to-consumption multiproduct spatial equilibrium models for beef and pork, based on separate assumptions regarding 1975 per capita consumption levels for beef and pork. All production-to-consumption models are omitted from this presentation but are available from the authors.

Western Ohio was an exporter of live hogs for slaughter in 1962, with slaughter within the region in balance with consumption. Eastern Ohio imported hogs for slaughter and was also an importer of carcass pork. The same situation prevailed under projected 1975 conditions except that Western Ohio was an importer of carcass pork despite continued exports of slaughter hogs.

Prospects appeared favorable for expanded hog slaughter activity in Western Ohio in view of existing and projected exports of live hogs, a favorable competitive position in respect to Eastern pork deficit markets, and prospective increases in hog production in Western Ohio and Indiana. However, with a trend toward more production-oriented

slaughter, Eastern Ohio appears likely to show a continuing decline in slaughter activity.

Both Eastern and Western Ohio were importers of slaughter cattle and carcass beef and veal in 1962 and similar patterns are forecast for 1975. Projected increases in beef production in Western Ohio appear adequate to support a moderate increase in cattle slaughter activity. Eastern Ohio was a substantial importer of live cattle and calves for slaughter in 1962. Despite a projection for some increase in beef production in that region by 1975, transfer cost advantages for carcass beef over live animals may result in some further reduction of beef slaughter in Eastern Ohio by 1975.

The national analysis revealed several potentially promising regions for increased slaughter activity in areas outside Ohio. Alabama and Mississippi appeared to be in a favorable position to expand hog slaughter activity, as did the Arkansas-Louisiana region. Increases in hog slaughter also seem justified in Illinois, Indiana, and Iowa on the basis of expected increases in hog production and current heavy exports of slaughter hogs. By contrast, the Minnesota-Wisconsin region appeared to be at a competitive disadvantage with other midwest states in terms of expanding slaughter for hogs.

A strong potential for greater cattle slaughter activity in Illinois and the Arizona-New Mexico region was revealed by the 1962 and 1975 solutions. Both regions were exporters of large numbers of live cattle and calves in 1962 but did not slaughter enough to meet consumption requirements within the region. Opportunity for expanded cattle and calf slaughter is apparent in the Western Corn Belt, the Montana-Wyoming-Idaho region, the Oklahoma-Texas region, and the Kentucky-Tennessee region.

The multiproduct spatial equilibrium procedure developed and applied in this study appears to offer some advantage in more accurate specification of regional demands, under certain conditions, over single-product models. A comparison of single-product and multiproduct solutions in this investigation revealed comparatively small differences in regional demand estimates. Greatest advantage of the multiproduct procedure over the single-product approach appears to be in models where there are sizable price differentials between regions within the total market and when the demand relationship reflects fairly high cross-product elasticities.

INTRODUCTION

This study is part of a 3-year investigation into procurement and other operational procedures of the Ohio meat processing industry in an analysis of Ohio's present and future competitive position in interregional livestock and meat trade.

Earlier phases of the investigation developed optimum procurement and distribution patterns for the hog-pork sector of the Ohio and national livestock and meat economy. They included a detailed presentation of the analytical method.[1] More recent research concentrated on the procurement methods and sources, plant size and capacity, distribution channels and sales outlets, and other descriptive features of the Ohio livestock slaughter industry.[2]

This study was directed toward investigating the present and potential competitive position of both the beef and pork industries in Ohio and to estimate optimum shipment patterns for slaughter cattle, calves, and hogs, and for beef, veal, and pork between 29 regions of the United States in both 1962 and 1975. Transportation and spatial equilibrium models were the primary analytical techniques employed.

Given the relevant information with regard to state or area production, slaughter, and consumption of pork, beef, and veal, the objective of transportation and spatial equilibrium analysis is to estimate basic interrelationships among these activities and to generalize the interstate and interregional shipment patterns that would result in minimizing aggregate transportation costs and maximizing product value added. Resulting solutions provide insights into patterns of competition between states and regions. They provide one basis for long-range managerial decisions regarding optimum markets and procurement sources, area buying and selling strategy, desirable slaughtering locations, and related policy matters.

While the analytical procedure itself is rather straightforward, the generalized results necessarily are limited in both their scope and their accuracy by the limits of the data employed. It is therefore appropriate that the reader be presented with the data and its use, as well as the conclusions. Then he can evaluate the results in his own terms and circumstances. This publication presents the data and its development carefully but does not explain the construction of the transportation and

[1]Stout, Thomas T., Ernest R. Bentley, and Francis E. Walker. 1963. Econometric Generalizations of the Ohio Hog-Pork Industry in Interregional Competition. Ohio Agricultural Experiment Station. Res. Bull. 950.

[2]Stout, Thomas T. and Ronald W. Dickey. 1964. The Ohio Livestock Slaughter Industry — A Survey. Ohio Agricultural Experiment Station. Res. Circ. 134.

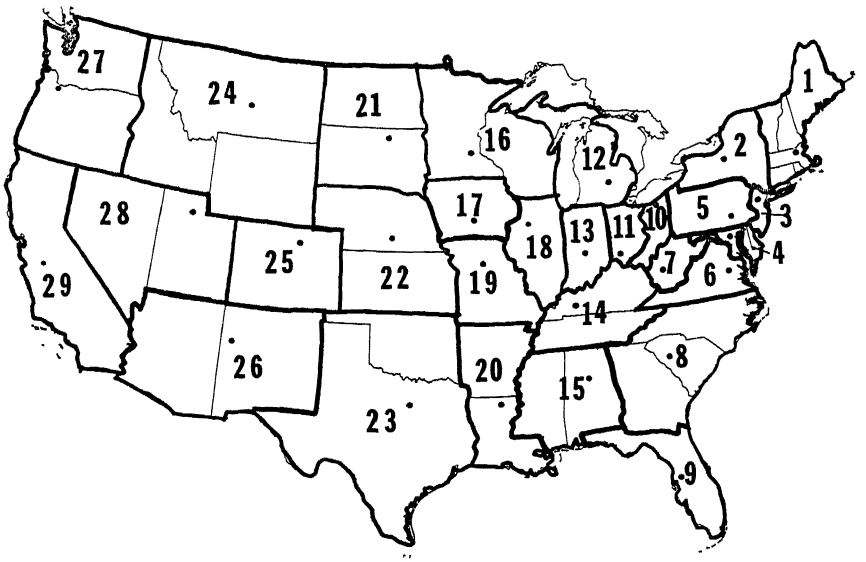

Fig. 1.—Regions and Basing Points, Transportation and Spatial Equilibrium Analysis, 29 Region Models, United States, 1962 and 1975.

spatial equilibrium models.[3] Multiproduct models, however, are discussed in Appendix A.

PRODUCTION, SLAUGHTER, AND CONSUMPTION OF U. S. BEEF AND PORK IN 1962

Transportation models were used to obtain patterns of production-to-slaughter livestock shipments for both hogs and slaughter cattle and calves in 1962. Multiproduct spatial equilibrium models were employed to obtain interdependent beef-pork shipment solutions from slaughter to consumption.

The continental United States was divided into 29 regions (Table 1 and Fig. 1). Each region represents a geographic area of somewhat similar attributes in regard to pork and beef production, slaughter, and consumption.

In most cases, regional boundaries encompass either a single state or an aggregation of two or more contiguous states. Three exceptions

[3]The development of single-product models has been outlined in several publications. For example, see Judge, G. G. and T. D. Wallace. 1959. Spatial Price Equilibrium Analyses of the Livestock Economy (Part I). Oklahoma Agricultural Experiment Station. Tech. Bull. TB-78. Also, Stout, T. T., E. R. Bentley, and F. E. Walker. op. cit.

TABLE 1.—Regional Delineation, Basing Points, Population, and Per Capita Disposable Income, 29 Regions, United States, 1962.

Region	State	Basing Point	Population (1,000)	Per Capita Disposable Income ($)
1	Mass., Conn., R.I., Me., Vt., N.H.	Boston	10,644	2,262
2	N.Y. (N.Y.C. excluded)	Syracuse	6,365	2,468
3	N.J., N.Y.C., Phila.	Perth Amboy	21,646	2,424
4	Md., Del., D.C.	Baltimore	4,444	2,325
5	Pa. (Phila. excluded)	Harrisburg	7,012	2,031
6	Virginia	Richmond	4,177	1,777
7	W. Virginia	Charleston	1,773	1,569
8	N.C., S.C., Ga.	Columbia	11,267	1,487
9	Florida	Tampa	5,459	1,746
10	Eastern Ohio	Cleveland	5,533	2,079
11	Western Ohio	Dayton	4,564	2,103
12	Michigan	Lansing	7,991	2,080
13	Indiana	Indianapolis	4,715	2,004
14	Ky., Tenn.	Bowling Green	6,716	1,496
15	Ala., Miss.	Birmingham	5,606	1,308
16	Minn., Wisc.	St. Paul	7,567	1,946
17	Iowa	Des Moines	2,777	1,898
18	Illinois	Peoria	10,146	2,388
19	Missouri	Jefferson City	4,346	2,038
20	Ark., La.	Monroe	5,153	1,437
21	N. Dakota, S. Dakota	Aberdeen	1,363	1,583
22	Kans., Nebr.	Grand Island	3,703	1,932
23	Okla., Texas	Ft. Worth	12,565	1,769
24	Mont., Wyo., Idaho	Billings	1,772	1,784
25	Colorado	Denver	1,907	2,072
26	Ariz., N. Mexico	Gallup	2,529	1,759
27	Wash., Ore.	Portland	4,870	2,056
28	Nev., Utah	Salt Lake City	1,302	1,988
29	California	Fresno	16,971	2,430
	United States		184,883	2,029

Source: Population: Bureau of the Census, U. S. Department of Commerce. 1963. Statistical Abstract of the United States.

Disposable Income: Survey of Buying Power, Sales Management magazine. June 10, 1963.

Fig. 2.—Regional Division of Ohio.

should be noted: Ohio was divided into two regions (Regions 10 and 11, Fig. 2). Since considerably more cattle and hogs are produced in the western half of the state than in the eastern half, this division provides a more accurate indication of the competitive position of the Ohio beef and pork industries. Metropolitan New York City was excluded from Region 2 (New York) and was included with Region 3. Similarly, Philadelphia was excluded from Region 5 (Pennsylvania) and included with Region 3. Thus Region 3 consisted of New Jersey, New York City, and Philadelphia.

Data Inputs

Basic data requirements for the 1962 analysis required:

- Population by regions and for the United States.
- Disposable income per capita by regions and for the United States.
- Production of hogs, cattle, and calves for slaughter by regions and for the United States, both liveweight and carcass weight.
- Total slaughter (commercial and farm) of hogs, cattle, and calves by regions and for the United States, both liveweight and carcass weight.
- Transportation costs per unit for meat and live animals between regions.
- U. S. average retail prices on beef and pork, base region retail prices for these meats, and price differentials from the base region for each region.
- Consumption of beef, veal, and pork by regions and for the United States, both per capita and total in carcass and retail weights.

Regional and national demand functions were required for both beef and pork to estimate regional per capita consumption. Data sources, adjustments, and description of the demand functions are discussed in this section. Data available in published series are presented in Tables 1, 2, and 3. Procedures used in allocating Ohio production and slaughter of hogs, cattle, and calves between regions 10 and 11 are discussed in Appendix B.

Population and Income Data

Population data used are for July 1, 1962, as published by the Bureau of the Census, U. S. Department of Commerce.

Data on disposable income per capita by regions was obtained from the annual Survey of Buying Power published in 1963 by Sales Management magazine. Averages for regions involving more than one state were computed by aggregating total disposable income for the region and dividing by total population. Average disposable income per capita for the two Ohio regions was obtained by aggregating county disposable income and population data for each region and dividing by population.

Production Data on Hogs, Cattle, and Calves

Hogs: Regional estimates of hog production for slaughter in 1962 were derived from data published by the U. S. Department of Agriculture.[4] Data on hog marketings (pounds liveweight) by states, plus estimated liveweight of hogs slaughtered on farms by states, were adjusted to equal total U. S. commercial slaughter of hogs plus farm slaughter of hogs.

Interfarm marketings are excluded from the U. S. data series on hog marketings. An adjustment factor of .9858 was required to equate estimated production plus farm slaughter with published data on commercial slaughter plus farm slaughter of hogs. The data were then aggregated to correspond to the regional boundaries used in the analysis. Hog production data expressed in both liveweight and carcass weight for the 29 regions are presented in Table 2.

Cattle and Calves: Developing suitable estimates of regional production of cattle and calves for slaughter is a complex and hazardous undertaking. A large proportion of the cattle produced and marketed in some states are sold as feeder cattle and calves. Data published by the U. S. Department of Agriculture on production and marketing of cattle and calves aggregates sales of stocker and feeder cattle,

[4]U. S. Department of Agriculture 1963. Livestock and Meat Statistics, 1962. Stat. Bull. 333, pp. 41-42, 158, 203.

TABLE 2.—Hog Production, Hog Slaughter, and Pork Production, 29 Regions, United States, 1962.

Region	State	Hog Production* 1,000 Lbs. Liveweight	Hog Slaughter† 1,000 Lbs. Liveweight	Pork Production‡ 1,000 Lbs. Carcass Weight	Pork Production (Slaughter)§ 1,000 Lbs. Carcass Weight
1	Mass., Conn., R.I., Me., Vt., N.H.	46,051	158,850	27,251	94,000
2	N.Y. (N.Y.C. excluded)	32,517	336,729	19,242	199,260
3	N.J., N.Y.C., Phila.	27,775	298,912	16,436	176,881
4	Md., Del., D.C.	64,423	151,275	38,122	89,517
5	Pa. (Phila. excluded)	153,689	672,043	90,946	397,682
6	Virginia	198,325	534,759	117,359	316,444
7	West Virginia	27,951	43,200	16,540	25,564
8	N.C., S.C., Ga.	906,249	923,049	536,273	546,215
9	Florida	90,635	131,721	53,633	77,946
10	Eastern Ohio	165,351**	430,386††	97,846	254,681
11	Western Ohio	753,268**	538,952††	445,747	318,925
12	Michigan	259,915	410,582	153,805	242,962
13	Indiana	1,894,117	1,272,384	1,120,844	742,934
14	Ky., Tenn.	794,181	1,003,850	469,957	594,029
15	Ala., Miss.	412,723	393,401	244,229	232,795
16	Minn., Wisc.	2,090,661	2,222,800	1,237,150	1,315,342
17	Iowa	4,516,840	3,590,106	2,672,843	2,124,446
18	Illinois	2,821,369	1,448,541	1,669,546	857,174
19	Missouri	1,400,990	1,026,787	829,036	607,602
20	Ark., La.	170,745	162,029	101,038	95,881
21	N. Dakota, S. Dakota	835,987	677,142	494,696	400,699
22	Nebr., Kans.	1,479,332	1,862,731	875,395	1,102,271
23	Okla., Texas	437,122	624,224	258,667	369,385
24	Mont., Idaho, Wyo.	117,748	116,765	69,677	69,096
25	Colorado	66,447	157,519	39,320	93,212
26	N. Mex., Ariz.	22,276	59,774	13,182	35,371
27	Wash., Ore.	101,767	281,127	60,221	166,357
28	Nev., Utah	22,322	68,664	13,209	40,632
29	California	99,350	411,824	58,790	243,697
	United States	20,010,126	20,010,126	11,841,000	11,841,000

*Hog marketings plus farm slaughter, adjusted to equal total U. S. hog slaughter.

†Commercial hog slaughter plus farm slaughter.

‡Hog marketings plus farm slaughter converted to carcass weight to equal total commercial production of carcass pork plus farm slaughter (liveweight x .59175039).

§Total hog slaughter (liveweight converted to carcass weight) (liveweight x .59175039).

**Estimates for regions 10 and 11 obtained from percentages of total cash receipts from sale of hogs in 1962 in counties in each region (region 10 = 18 percent; region 11 = 82 percent).

††Total Ohio slaughter is allocated between regions 10 and 11 in proportion to actual slaughter in the two regions as reported by meat packers and processors in Ohio in 1961 (region 10 = 44.4 percent; region 11 = 55.6 percent).

Source: U. S. Department of Agriculture. 1963. Livestock and Meat Statistics, 1962. Stat. Bull. 333, pp. 41-42, 158 and 203.

dairy cattle, and slaughter cattle and calves. As a result, published data are not satisfactory for estimating an individual state's production of cattle and calves for slaughter. Similarly, published data on cattle and calf slaughter by states is not satisfactory since slaughter does not necessarily occur in the state where the cattle were produced and marketed.

Estimates of regional production of cattle and calves for slaughter were derived by subtracting the estimated marketings of non-slaughter cattle and calves from given data on total cattle and calf marketings (pounds liveweight).[5] Farm slaughter of cattle and calves was then added to yield an estimate of total production for slaughter. These production estimates were equal to total U. S. commercial slaughter of cattle and calves plus farm slaughter (Table 3). The procedure for estimating regional production of cattle and calves for slaughter is presented in detail in Appendix C.

Slaughter Data on Beef and Pork

Data on commercial cattle, calf, and hog slaughter by states, both liveweight and carcass weight basis, is published by the U. S. Department of Agriculture.[6] (Carcass weights were converted to retail equivalent weights in computations involving demand relationships in the slaughter-to-consumption shipment analyses.)

Data also are available on the number of each class of livestock slaughtered on farms in each state, as well as the average weights of farm-slaughtered livestock in the United States. U. S. average weights were used uniformly for all states in estimating the actual volume of farm-slaughtered beef and pork.

These state totals on commercial and farm slaughter of hogs, cattle and calves were aggregated to yield regional slaughter totals (Tables 2 and 3).

Transportation Rates on Livestock and Meat

The transportation functions for live animals were developed as a part of earlier research.[7] Live rates are based on truck transportation rates and highway mileages. They are independent of volume shipped but are direction-dependent, with somewhat higher transportation charges on eastbound shipments than on westbound.

Two sets of direction-dependent functions for estimating transportation charges were developed by regression analysis:

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[5]U. S. Department of Agriculture. 1963. Livestock and Meat Statistics, 1962. Stat. Bull. 333, pp. 37-38, 158, 201-202.

[6]Ibid.

[7]Stout, T. T., E. R. Bentley, and F. E. Walker. op. cit.

TABLE 3.—Cattle and Calf Production for Slaughter, Cattle and Calf Slaughter, and Beef and Veal Production, 29 Regions, United States, 1962.

Region	State	Cattle and Calf Production* 1,000 Lbs. Liveweight	Cattle and Calf Slaughter† 1,000 Lbs. Liveweight	Beef and Veal Production‡ 1,000 Lbs. Carcass Weight	Beef and Veal Production (Slaughter)§ 1,000 Lbs. Carcass Weight
1	Mass., Me., Vt., N.H., Conn., R.I.	235,042	280,515	133,326	159,120
2	N.Y. (N.Y.C. excluded)	415,963	657,803	235,951	373,133
3	N.J., N.Y.C., Phila.	59,699	612,484	33,864	347,426
4	Md., Del., D.C.	145,971	157,154	82,801	89,144
5	Pa. (Phila. excluded)	499,782	1,078,657	283,497	611,859
6	Virginia	233,495	246,944	132,448	140,077
7	W. Virginia	85,321	74,270	48,398	42,129
8	N.C., S. C., Ga.	344,880	597,503	195,630	338,929
9	Florida	79,342	352,587	45,006	200,002
10	Eastern Ohio	263,397**	595,220††	149,410	337,633
11	Western Ohio	468,262**	607,244††	265,618	344,454
12	Michigan	496,818	824,478	281,816	467,678
13	Indiana	692,143	791,504	392,612	448,974
14	Ky., Tenn.	737,678	630,064	418,442	357,398
15	Ala., Miss.	494,004	511,163	280,220	289,953
16	Minn., Wisc.	2,599,579	2,653,564	1,474,589	1,505,212
17	Iowa	3,588,843	3,211,998	2,035,740	1,821,979
18	Illinois	1,946,541	1,374,139	1,104,159	799,469
19	Missouri	1,091,699	1,168,729	619,257	662,952
20	Ark., La.	294,044	345,258	166,794	195,845
21	N. Dakota, S. Dak.	1,180,555	660,361	669,660	374,584
22	Nebr., Kans.	3,946,441	3,516,242	2,238,584	1,994,558
23	Okla., Texas	2,880,764	2,136,652	1,634,088	1,211,998
24	Mont., Idaho, W,o.	880,984	372,085	499,731	211,062
25	Colorado	1,232,476	1,213,478	699,112	688,335
26	N. Mex., Ariz.	986,119	275,770	559,368	156,428
27	Wash., Ore.	518,582	791,351	294,161	448,887
28	Nev., Utah	194,370	269,802	110,255	153,043
29	California	2,135,709	2,721,484	1,211,463	1,543,739
	United States	28,728,503	28,728,503	16,296,000	16,296,000

*Marketings of cattle and calves plus farm slaughter of cattle and calves, less estimated marketings of non-slaughter cattle and calves.

†Commercial slaughter of cattle and calves plus farm slaughter.

‡Liveweight production adjusted to carcass basis to equal total production of carcass beef and veal.

§Liveweight slaughter adjusted to carcass basis to equal total commercial slaughter of beef and veal plus farm slaughter.

**Estimates for regions 10 and 11 obtained from percentages of total cash receipts from sale of cattle and calves in 1962 in counties in each region (region 10 = 36 percent; region 11 = 64 percent)..

††Total Ohio slaughter of beef and veal allocated between regions 10 and 11 in proportion to actual slaughter in the two regions as reported by meat packers and processors in 1961 (region 10 = 49.5 percent; region 11 = 50.5 percent).

Source: U. S. Department of Agriculture. 1963. Livestock and Meat Statistics, 1962. Stat. Bull. 333, pp. 37-38, 158 and 201-202.

Eastbound shipments:

1. $C_{ij} = 14.6744 + .1531M_{ij} - .00004792M^2_{ij}$ (0-300 miles)
2. $C_{ij} = 12.9834 + .1464M_{ij}$ (300-2000 miles)

where:

C_{ij} = liveweight transportation cost from region i to region j in cents per pound or dollars per hundredweight

M_{ij} = highway mileage from region i to region j

Westbound shipments:

1. $C_{ij} = 13.5814 + .1605M_{ij} - .00008325M^2_{ij}$ (0-400 miles)
2. $C_{ij} = 17.6260 + .11544M_{ij}$ (400-2000 miles)

The transportation function used for meat was developed at the University of Illinois.[8] It is based on a combination of both truck and rail rates and all distances are represented by a single function:

$$C_{ij} = 21.4856 + .1929M_{ij} - .00001979M^2_{ij}$$

Retail Price and Consumption Data

Annual data on the U. S. average retail price of pork are available from published sources. Retail price data on beef are published on a regular basis for only selected retail cuts and for a composite of cuts from Choice grade carcasses. Estimates of annual U. S. average retail prices for all beef were obtained for 1959 and 1960 from published sources. Data for 1961 and 1962 were derived by procedures discussed in this same source.[9] These price and consumption data and sources of data are presented in Tables 4 and 5.

[8]The transportation cost function for meat was provided by Dr. G. G. Judge, Department of Agricultural Economics, University of Illinois. It was developed by Dr. Judge and associates in connection with research at that institution. Dr. Judge emphasizes the preliminary nature of the rate function and has since worked toward refinement which may yield parameters significantly different from those cited in the equation.

[9]Sources noted in footnotes to Tables 4 and 5.

TABLE 4.—Beef and Veal, Per Capita Consumption and Retail Price per Pound, United States, 1959-62 Average.

Year	Per Capita Consumption						Retail Price of Beef†
	Carcass Weight			Retail Weight*			
	Beef	Veal	Beef and Veal	Beef	Veal	Beef and Veal	
	(Pounds)			(Pounds)			(Cents/Pound)
1959	81.4	5.7	87.1	64.3	5 2	69.5	76.8
1960	85.2	6.2	91.4	67.3	5.6	72.9	74.2
1961	88.0	5.7	93.7	69.5	5 2	74.7	74.5
1962	89.1	5.5	94.6	70.4	5.0	75.4	76.6
Average 1959-62	85.9	5.8	91.7	67.9	5.2	73.1	75.5

*Carcass weights converted to retail weights by standard conversion factors of .79 for beef and .91 for veal.

†Estimated U. S. average retail price of all beef.

Source: Consumption Data: U. S. Department of Agriculture. 1963. Livestock and Meat Statistics 1962. Stat. Bull. 333, p. 289.

Carcass to retail conversion factors: U. S. Department of Agriculture. 1960. Meat Consumption Trends and Patterns. Agr. Handbook No. 187, p. 44.

Retail prices: Data for 1955-1960—U. S. Department of Agriculture. 1961. Demand and Prices for Meat. Tech. Bull. 1253. Data for 1961 and 1962 developed by procedures discussed in this reference.

National Demand Functions for Beef and Pork

The national demand functions employed in this study are as follows:

$$Q_p = a_1 + b_1P_p + b_2P_b + c_1I$$
$$Q_b = a_2 + b_3P_b + b_4P_p + c_2I$$

where:

Q_p = U. S. average annual per capita consumption of pork, retail pounds

Q_b = U. S. average annual per capita consumption of beef and veal, retail pounds

P_p = U. S. average retail price of pork, cents per pound

P_b = U. S. average retail price of beef (including veal), cents per pound.

I = U. S. average per capita disposable income

All price and income data used in the 1962 functions are in current dollars. Parameters for the demand equations were developed from

TABLE 5.—Pork Consumption per Capita, Retail Price of Pork per Pound, and Per Capita Disposable Income, United States, 1959-62 Average.

Year	Per Capita Consumption* Carcass Wt. (Pounds)	Per Capita Consumption* Retail Wt.† (Pounds)	Retail Price (Cents/Pound)	Disposable Income Per Capita (Dollars)
1959	67.6	62.9	57.1	1,866
1960	65.2	60.6	56.7	1,974
1961	63.2	58.8	59.2	1,967
1962	63.9	59.4	59.5	2,029
Average 1959-62	65.0	60.4	58.1	1,959

*Excluding lard.

†Carcass weight multiplied by standard conversion factor of .93.

Source: U. S. Department of Agriculture. 1963. Livestock and Meat Statistics, 1962. Stat. Bull. 333, pp. 280 and 289.

Carcass to retail conversion factor: U. S. Department of Agriculture. 1960. Meat Consumption Trends and Patterns Agri. Handbook No. 187, p. 44.

Disposable Income: Survey of Buying Power, Sales Management magazine, annual issues, 1960 through 1963.

published price, income, and cross-elasticities for beef and pork and 1959-62 price, income, and consumption data.

Per capita demand for beef in the United States has trended upward during the past 15 years. A part of this increased demand apparently has resulted from a change in consumer preferences toward beef. This trend effect, not explained by prices and income, is estimated to have resulted in a 1.18 percent annual increase in per capita consumption of beef for the period 1948-1958.[10] During the same period, similar trend factors are estimated to have caused a decrease in per capita consumption of pork averaging 1.59 percent annually. Real disposable income per capita increased at an average rate of 1.8 percent annually from 1948 through 1959.

As a result of these concurrent trends, least-squares procedures employing price and income as the primary variables tend to allocate trend effects into the income parameter. This effect becomes most apparent in estimating regional consumption per capita, since per capita income shows wide regional variation and since significant differences

[10]Brandow, G. E. 1961. Interrelations Among Demands for Farm Products and Implications for Control of Market Supply. Pennsylvania Agricultural Experiment Station. Bull. 680.

in regional preferences for beef and pork have been revealed by past research.[11]

The specific procedures for developing the coefficients used in the beef and pork demand functions were based on these relationships between elasticities and price-quantity coefficients:

$$b = \frac{\text{Change in Quantity}}{\text{Change in Price}} = \frac{\triangle Q}{\triangle P}$$

$$E_D = \frac{\triangle Q}{\triangle P} \bullet \frac{P}{Q}$$

therefore:

$$b = E_D \bullet \frac{Q}{P}$$

Price, income, and cross-elasticities for beef and pork were taken from published research.[12]

Pork:	
Price elasticity of demand at retail	—.75000
Cross-elasticity of beef price at retail	.10019
Income elasticity of demand at retail	.22000
Beef:	
Price elasticity of demand at retail	—.95000
Cross-elasticity of pork price at retail	.13367
Income elasticity of demand at retail	.37000

Price, consumption and income data used in developing the coefficients were averages for the years 1959-62 (Tables 4 and 5).

Coefficients were computed by substituting indicated elasticities and 1959-62 data on average per capita disposable income, beef and pork prices, and per capita consumption in the equation:

$$b = E_D \bullet \frac{Q}{P}$$

This procedure yielded the coefficients:

$b_1 = .779690$
$b_2 = .080152$
$b_3 = .921059$
$b_4 = .168410$
$c_1 = .006783$
$c_2 = .013825$

[11]U. S. Department of Agriculture. 1960. Meat Consumption Trends and Patterns. Agricultural Handbook No. 187 (results and analysis of survey data on meat consumption obtained in the 1955 Household Food Consumption Survey).

[12]Brandow, G. E. op. cit.

With known values for all variables and coefficients in the demand functions except a_1 and a_2, these values were computed algebraically by substitution. The procedure yielded the following 1962 demand functions for pork and beef, with variables as previously defined:

$$Q_p = 86.360616 - .779690P_p + .080152P_b + .006783\ I$$
$$Q_b = 105.872159 - .921059P_b + .168410P_p + .013825\ I$$

Regional Demand Functions for Beef and Pork

The regional demand functions for beef and pork were identical in form to the national demand functions. The same national coefficients were employed except separate vertical intercepts (a-values) were derived for each region in the set of regional demand functions (Table 6) to reflect apparent regional differences in preference for beef and pork. These are related to factors such as population composition, tradition, and habit.

Slopes of regional demand functions were assumed to be the same in all regions and the same as the national demand function, although the level of the function varied between regions. The development of regional functions is discussed in greater detail in Appendix D.

OPTIMUM INTERREGIONAL TRADE PATTERNS FOR 1962

Two transportation models and two multiproduct spatial equilibrium models are presented to describe interregional shipment patterns generated for 1962. The two transportation models generalize production-to-slaughter shipment flows for hogs and for cattle and calves. The two spatial equilibrium models describe optimum trade patterns for pork and for beef and veal shipments moving from surplus slaughter regions to consumption regions that import meat.

This section is concerned only with product flows. It does not present regional price and consumption levels, which appear in a later section.[13]

In evaluating these models, it should be recognized that the solutions develop shipment patterns on the basis of net surpluses and net deficits only. All shipments that would realistically occur within regions will be obscured in the solutions. While the solutions do not restate the interregional trading that occured in 1962, they try to approximate the nature and direction of product flow and the price relationships characterizing actual 1962 trade. Errors that may be discovered will be attributable

[13]Additional solutions omitted from this presentation included multiproduct spatial equilibrium models for production-to-consumption flows for beef and pork, assuming production-oriented slaughter, and single product spatial models for slaughter-to-consumption shipments. Questions regarding these models may be directed to the authors.

not so much to the analytical method as to the nature and accuracy of the data submitted for analysis.

Production-to-Slaughter Shipments

Hogs: The optimum (least-cost) shipment pattern of live hogs from surplus production regions to surplus slaughter regions (deficit in relation to slaughter requirements) for 1962 is presented in Table 7.

TABLE 6.—Vertical Intercepts for Regional Demand Functions, Pork and Beef, 29 Region Spatial Equilibrium Models, United States, 1962 and 1975.

Region	Pork 1962	Pork 1975 Assumption I	Pork 1975 Assumption II	Beef 1962	Beef 1975 Assumption I	Beef 1975 Assumption II
1	76.3572	60.8612	66.1788	107.1645	122.6041	114.2468
2	75.4754	60.4339	65.7515	105.3673	121.7492	113.3919
3	74.9735	58.8060	64.1236	104.3442	118.4924	110.1354
4	76.0791	59.1112	64.4288	106.5977	119.1031	110.7460
5	77.8698	63.4863	68.8039	110.2475	127.8556	119.4878
6	94.4210	77.2185	83.4449	85.1257	93.3814	87.2901
7	95.6555	79.3552	85.5815	87.6418	97.6559	91.5643
8	96.4695	79.9249	86.1513	89.3008	98.7958	92.7041
9	95.1972	77.7612	83.9875	84.6695	94.4670	88.3756
10	90.5453	73.7861	79.9150	118.4426	138.7455	129.6468
11	90.4232	73.6301	79.7590	118.1938	138.4334	129.3347
12	90.7216	74.0710	80.1999	118.8021	139.3154	130.2167
13	91.3117	74.1388	80.2678	120.0048	139.4511	130.3524
14	96.4424	79.9249	86.1513	89.2455	98.7958	92.7041
15	97.4937	81.2273	87.4536	91.3884	101.4012	95.3093
16	91.8001	75.1359	81.2649	121.0002	141.4458	132.3469
17	92.0918	74.9595	81.0885	121.5947	141.0930	131.9942
18	88.7342	71.1746	77.3036	114.7513	133.5211	124.4228
19	92.1286	72.9314	79.0604	119.6316	137.0357	127.9371
20	96.5102	79.4501	85.6765	89.3838	97.8458	91.7543
21	94.1606	80.3045	86.4335	125.8113	151.7860	142.6864
22	91.8679	75.7057	81.8346	121.1385	142.5857	133.4867
23	94.4685	77.4356	83.6619	85.2225	93.8157	87.7243
24	80.2386	67.3955	72.7780	128.3263	154.0477	144.4692
25	78.6650	64.3092	69.6917	125.1189	147.8736	138.2954
26	80.7338	66.3170	71.6995	129.3355	151.8902	142.3118
27	78.6989	64.6891	70.0715	125.1880	148.6335	139.0553
28	79.4382	64.7230	70.1055	126.6949	148.7014	139.1231
29	76.1559	60.5650	65.9475	120.0036	140.3831	130.8055

Source: Original data.

TABLE 7.—Pork Transportation Model, Production to Slaughter. Optimum Shipment Pattern for Hogs, Surplus Production Regions to Surplus Slaughter Regions, 29 Regions, United States, 1962. (Transportation Cost — $41,699,652).

Deficit Production Region*	Surplus Production Region									Total Destination Requirements†
	11	13	15	17	18	19	20	21	24	
	Volume of Shipments and Non-Optimal Cost Coefficients‡									
1	.04	.05	1.00	.36	**112.8**	.25	1.22	1.32	3.48	**112.8**
2	.22	.20	1.27	.34	**304.2**	.29	1.45	1.30	2.94	**304.2**
3	.01	.01	.97	.34	**271.1**	.18	1.23	1.37	2.82	**271.1**
4	**86.9**	.00	.90	.39	.01	.24	1.11	1.37	2.83	**86.9**
5	**127.5**	**253.2**	.96	.38	**137.6**	.22	1.22	1.38	2.83	**518.3**
6	.03	**336.4**	.67	.44	.03	.20	1.94	1.43	2.89	**336.4**
7	.01	**15.3**	.81	.53	.04	.21	1.12	1.47	2.93	**15.3**
8	.10	**16.8**	.23	.43	.03	.09	.42	1.47	2.93	**16.8**
9	.23	.11	**19.3**	.38	**13.1**	.02	**8.7**	1.57	3.00	**41.1**
10	.06	.05	1.25	.36	**265.0**	.29	1.27	1.31	2.75	**265.0**
12	.27	.15	1.44	.33	**150.7**	.36	1.52	.29	3.33	**150.7**
14	.28	.07	.66	.28	**118.3**	**91.4**	.68	1.54	2.95	**209.7**
16	.89	61	1.70	**132.1**	.13	.21	1.75	.46	2.06	**132.1**
22	1.02	.74	1.70	**383.4**	.11	.16	1.24	.53	1.83	**383.4**
23	.87	.58	.86	.09	.18	**187.1**	.15	.91	2.24	**187.1**
25	.96	.68	1.59	**91.1**	.23	.23	.98	.56	.94	**91.1**
26	.93	80	1.30	.07	.21	**37.5**	.58	.77	1.05	**37.5**
27	1.09	.81	1.72	**19.5**	.24	.49	1.26	**158.9**	**1.0**	**179.4**
28	1.05	.77	1.67	**46.3**	.24	.39	1.05	28	.62	**46.3**
29	.93	.66	.99	**254.3**	.23	**58.2**	.54	.16	.37	**312.5**
Total Shipments†	**214.4**	**621.7**	**19.3**	**926.7**	**1,372.8**	**374.2**	**8.7**	**158.9**	**1.0**	**3,697.7**

*These may also be regarded as surplus slaughter regions in relation to regional production.

†Millions of pounds liveweight.

‡Bold face numbers are live hog shipments in millions of pounds liveweight; remaining values represent additional transportation costs per unit (dollars per hundredweight or cents per pound) that would be incurred if a shipment were made between the pair of regions represented by the particular cell.

Source: Original data.

Numerical designations for the different regions correspond to those presented in Table 1 and Fig. 1.

The total shipment and destination requirements (rim requirements) show the total quantity each region must ship or receive. The pattern and volume of shipments are shown in the table field, with bold face numbers representing shipments of hogs in millions of pounds liveweight. Thus region 6 (Virginia), with a net deficit of 336.4 million pounds, received all of this quantity from region 13 (Indiana). Similarly, region 15 (Alabama-Mississippi), with a net surplus of 19.3 million pounds, shipped this entire quantity to region 9 (Florida).

The value in cells where no shipments occurred are identified as non-optimal cost coefficients. These values are the amounts by which unit transfer costs from a surplus region to a deficit region exceeded the unit value difference of the product between those same regions.

The non-optimal costs represent additions to the total cost of transportation that would result for each unit shipped between such regions. For example, a shipment from region 11 (Western Ohio) to region 9 (Florida) would increase the total transportation bill 23 cents for each 100 pounds of live hogs shipped. The important feature of the information is that, to Ohio exporters or others, this means a considerable disadvantage in competing with other regions for that particular market.

The 1962 production-to-slaughter model for live hogs included 9 surplus regions and 20 deficit regions. In this shipment pattern, region 11 (Western Ohio) was an exporter of live hogs for slaughter and region 10 (Eastern Ohio) was a net importer of live hogs. However, in the optimum solution, live hogs were not shipped from region 11 to region 10. Rather, surplus production (above regional slaughter) in region 11 was exported to region 4 (Maryland-Delaware-D.C.) and to region 5 (Pennsylvania). Additional slaughter requirements in region 10 were imported from region 18 (Illinois) and possibly from region 13 (Indiana). Shipments to region 10 from region 11 under 1962 optimum conditions would result in a net loss of 6 cents per hundredweight of hogs shipped.[14]

Region 18 (Illinois) was the largest single exporter of live hogs in the 1962 optimum solution. Illinois, Indiana, and Western Ohio (regions 18, 13, and 11) were the major exporters to deficit regions in the Eastern United States. Regions 17 and 19 (Iowa and Missouri) were major shippers of live hogs to the West and Southwest. Non-optimal cost coefficients indicated that Western Ohio could ship to region 1

[14]While actual shipments between these regions occurred in 1962, the optimum pattern accurately emphasizes the importance of Eastern markets to Western Ohio producers and generates shipments to important Eastern areas that actually were made in 1962.

(New England), region 3 (New Jersey-New York City-Philadelphia), region 6 (Virginia), region 7 (West Virginia), or region 10 (Eastern Ohio) at a slight additional cost relative to the optimum.

Cattle and Calves: The transportation model optimum production-slaughter shipment pattern for beef and veal in 1962 is presented in Table 8. Both Western and Eastern Ohio (regions 10 and 11) were importers of live cattle and calves to meet total slaughter requirements in 1962. Region 10 received shipments from region 22 (Kansas-Nebraska) and region 24 (Montana-Wyoming-Idaho) in the optimum solution. Region 11 imported cattle for slaughter from regions 22 (Kansas-Nebraska) and 23 (Oklahoma-Texas).

The solution indicated that Western Ohio could obtain slaughter cattle from region 14 (Kentucky-Tennessee) and region 18 (Illinois) at slight additional cost and that region 17 (Iowa) and regions 24 (Montana-Wyoming-Idaho), 25 (Colorado), and 26 (Arizona-New Mexico) were possible supply sources at fairly small additional cost.

Alternative sources of supply for Eastern Ohio were more limited. However, live cattle could be obtained from regions 17, 18, and 21 (Iowa, Illinois, North and South Dakota) at a small competitive disadvantage.

All major surplus regions for live cattle and calves, in relation to regional slaughter requirements, were located in the Western Corn Belt and the West, resulting in a predominant West-to-East pattern of shipments.

Slaughter-to-Consumption Shipments—Multiproduct Solutions

Pork: An optimum shipment pattern for pork moving from surplus slaughter regions to consumption regions in 1962 is presented in Table 9. This multiproduct solution revealed region 11 (Western Ohio) as neither surplus nor deficit in pork slaughter, with regional consumption in balance with regional slaughter. Although it is shown as a deficit region in Table 9, zero imports are indicated.

Region 10 (Eastern Ohio) was an importer of pork in the optimum solution and received its requirements from region 16 (Minnesota-Wisconsin). Since the non-optimal cost coefficient for regions 18 (Illinois) and 10 (Eastern Ohio) is zero, such a shipment would represent an alternate optimum solution. Thus, region 10 could obtain pork from region 18 with no increase in the total transportation bill. Regions 13 (Indiana) and 17 (Iowa) could export to Eastern Ohio with only a slight increase in transportation costs.

In general, the distribution pattern showed regions 21 (North and South Dakota) and 22 (Kansas-Nebraska) shipping pork west, with

TABLE 8.—Beef Transportation Model, Production to Slaughter. Optimum Shipment Pattern for Cattle and Calves, Surplus Production Regions to Surplus Slaughter Regions, 29 Regions, United States, 1962. (Transportation Cost — $60,879,765).

Deficit Production Region*	Surplus Production Region										Total Destination Requirements†
	7	14	17	18	21	22	23	24	25	26	
	Volume of Shipments and Non-Optimal Cost Coefficients‡										
1	.04	.05	.02	**45.5**	0	0	.05	.68	.19	36	**45.5**
2	.33	.33	.02	.02	**241.8**	.15	.24	.16	49	.53	**241.8**
3	.06	.01	**376.9**	**175.9**	.05	.03	.02	.02	.12	.32	**552.8**
4	.05	**11.2**	.11	.07	.11	.10	.01	.09	.16	.39	**11.2**
5	**11.1**	**83.0**	.04	**351.0**	.05	**133.8**	.01	.03	.12	.31	**578.9**
6	.01	**13.4**	.38	.31	.39	30	0	.37	.46	.43	**13.4**
8	.78	.35	.77	.71	.83	.73	**252.6**	.81	.75	.43	**252.6**
9	1.23	.51	1.10	1.06	1 31	1.13	**273.2**	1.26	1.04	.62	**273.2**
10	.27	.18	.07	.05	.04	**95.7**	.13	**236.1**	.19	.25	**331.8**
11	.31	.02	.07	.01	.13	**88.5**	**50.5**	.10	.08	.10	**139.0**
12	.42	.26	.02	.03	**224.4**	**103.3**	.19	.56	.19	.43	**327.7**
13	.60	.13	.13	.05	.13	.01	**99.4**	.11	.08	.28	**99.4**
15	1.14	.52	.99	.97	1.16	.88	**17.2**	1.02	.88	.57	**17.2**
16	1.96	1.51	.52	.33	**54.0**	.45	.83	.12	.53	.99	**54.0**
19	1.33	.64	.16	.42	.37	**8.9**	0	.19	**19.0**	**49.1**	**77.0**
20	.30	.35	1.56	.70	1.78	1.23	**51.2**	1.37	1.05	.60	**51.2**
27	2.35	2.48	2.46	2.12	1.48	1 71	1.58	**272.8**	96	.61	**272.8**
28	1.10	1.27	1.93	.98	1.23	1.15	1.32	.09	.38	**75.4**	**75.4**
29	2.06	2.25	2.55	2.02	1.73	1 79	1.53	.46	.89	**585.8**	**585.8**
Total Shipments†	**11.1**	**107.6**	**376.9**	**572.4**	**520.2**	**430.2**	**744.1**	**508.9**	**19.0**	**710.3**	**4,000.7**

*These may also be regarded as surplus slaughter regions in relation to regional beef production.

†Millions of pounds liveweight.

‡Bold face numbers are cattle and calf shipments in millions of pounds liveweight; remaining values represent additional transportation costs per unit (dollars per hundredweight or cents per pound) that would be incurred if a shipment were made between the pair of regions represented by the particular cell.

Source: Original data.

TABLE 9.—Pork Multiproduct Spatial Equilibrium Model, Slaughter to Consumption. Optimum Shipment Pattern for Pork, Surplus Slaughter Regions to Surplus Consumption Regions, 29 Regions, United States, 1962 (Transportation Cost — $94,430,550).

Deficit Slaughter Region*	Surplus Slaughter Region										Total Destination Requirements†
	5	6	13	14	16	17	18	19	21	22	
	Volume of Shipments and Non-Optimal Cost Coefficients‡										
1	.12	.27	.15	.63	**488.9**	.02	.06	.42	55	.51	**488.9**
2	.35	.61	.27	.89	.16	**155.0**	.03	.45	.57	.67	**155.0**
3	**9.6**	.17	.07	.57	.05	**997.3**	.02	.33	.62	.55	**1,006.9**
4	.01	**18.1**	**66.9**	.44	.02	.02	**71.2**	.35	.60	.54	**156.2**
7	1.10	.76	**100.6**	.43	.19	.21	.06	.37	.79	.61	**100.6**
8	.85	.32	**254.0**	.13	.11	.05	.02	.19	.68	.54	**254.0**
9	1.17	.67	.17	.06	.11	**304.6**	.01	.14	.69	.43	**304.6**
10	.99	1.07	.05	.67	**129.5**	.02	.00	.45	.72	.53	**129.5**
11	—	—	—	—	—	—	—	—	—	—	**000.0**
12	1.59	1.65	.16	.93	**159.8**	**84.7**	**70.2**	.55	.64	.57	**314.7**
15	1.57	1.23	.16	**111.3**	.19	.00	.00	**54.1**	.78	.45	**165.4**
20	2.13	1.81	.42	.36	.24	**21.8**	.08	**247.3**	.82	.22	**269.1**
23	2.72	2.41	1.03	1.02	.28	**364.3**	.53	.40	.58	**160.5**	**524.8**
24	3.40	3.39	1.88	2.45	.31	.42	1.17	1.38	**30.3**	.32	**30.3**
25	3.36	3.37	1.67	2.13	.52	.39	1.11	1.31	.62	**15.0**	**15.0**
26	2.98	2.79	1.40	1.25	.53	.13	.71	.55	.51	**106.3**	**106.3**
27	3.04	2.99	1.65	2.04	.21	.43	1.06	1.39	**104.0**	.20	**104.0**
28	3.23	3.19	1.67	2.11	.46	.34	1.04	1.34	.19	**32.9**	**32.9**
29	2.75	2.70	1.33	1.74	.20	.24	.86	.75	**170.0**	**525.6**	**695.6**
Total Shipments†	**9.6**	**18.1**	**421.5**	**111.3**	**778.2**	**1,927.7**	**141.4**	**301.4**	**304.3**	**840.3**	**4,853.8**

*These may also be regarded as surplus consumption regions in relation to regional slaughter.

†Millions of pounds of carcass pork.

‡Bold face numbers are shipments of pork in millions of pounds carcass weight; remaining values represent additional transportion costs per unit (dollars per hundredweight or cents per pound) that would be incurred if a shipment were made between the pair of regions represented by a particular cell.

Source: Original data.

regions 17, 18, 13, and 16 (Iowa, Illinois, Indiana, and Minnesota-Wisconsin) making most of the shipments east. Shipments into deficit regions in the South originated largely in Iowa, Missouri and Indiana.

Regions 5, 6, 14, and 16 (Pennsylvania, Virginia, Kentucky-Tennessee, and Minnesota-Wisconsin), which were deficit production regions in relation to slaughter, became surplus regions in this slaughter-to-consumption model. This indicated imports of hogs for slaughter with consequent exports of carcass pork.

Regions 11, 15, and 20 (Western Ohio, Alabama-Mississippi, and Arkansas-Louisiana), which were surplus producers in relation to slaughter, were deficit in slaughter volume relative to consumption. Therefore, these three regions exported hogs to other regions for slaughter and imported carcass pork for consumption. Regional price relationships and per capita consumption estimates for the multiproduct 1962 solutions are shown in Table 11.

Beef: Both Eastern and Western Ohio were deficit in beef and veal requirements in relation to regional slaughter (Table 10). Eastern Ohio received beef from region 16 (Minnesota-Wisconsin), with region 22 (Kansas-Nebraska) a close competitor for the Eastern Ohio market. Regions 17 and 21 (Iowa, North and South Dakota) also could ship beef to Eastern Ohio at a small competitive disadvantage.

Western Ohio imported beef from region 22 (Kansas-Nebraska) in the optimum shipment pattern, with region 19 (Missouri) a potential supply source at slight additional cost. Price and per capita consumption estimates resulting from the analysis appear in Table 11.

FORECASTS FOR THE 1975 BEEF-PORK ECONOMY

Regional beef and pork production, slaughter, and consumption levels in 1975 were projected to provide a basis for estimating future competitive relationships for interregional movement of livestock and meat. Comparison of 1962 and projected 1975 conditions indicates adjustments that may be anticipated in shipment patterns and slaughter locations.

Three estimates of the beef-pork industries were developed for 1975. They reflect alternate assumptions regarding 1975 per capita consumption levels and 1975 slaughter locations.

Two alternate assumptions were made concerning consumption levels. The first, identified as assumption I, assumed basically a continuation of the 1948-58 trends in per capita consumption of pork, beef, and veal through 1975. Assumption II, a more conservative estimate, assumed that the 1948-58 average annual rate of change in consumption

TABLE 10.—Beef Multiproduct Spatial Equilibrium Model, Slaughter to Consumption. Optimum Shipment Pattern for Beef, Surplus Slaughter Regions to Surplus Consumption Regions, 29 Regions, United States, 1962 (Transportation Cost — $107,615,441).

Deficit Slaughter Region*	Surplus Slaughter Region									Total Destination Requirements†
	16	17	19	21	22	23	24	25	28	
	Volume of Shipments and Non-Optimal Cost Coefficients‡									
1	.01	.06	.15	**2.7**	**805.8**	.59	1.89	.66	1.84	**808.5**
2	.15	.02	.16	**215.8**	.14	.80	1.68	.96	1.08	**215.8**
3	.02	**1,533.3**	.02	.03	**77.1**	.57	1.51	.62	1.92	**1,610.4**
4	**137.6**	.03	.05	.02	**180.5**	.51	1.53	.61	1.93	**318.1**
5	.02	.04	.06	.05	**27.3**	.59	1.57	.65	1.97	**27.3**
6	.07	.08	.03	.08	**100.1**	.30	1.58	.68	1.95	**100.1**
7	.10	.13	**34.8**	.14	**25.2**	.37	1.70	.74	2.06	**60.0**
8	.20	.17	**104.3**	.21	.11	**209.4**	1.70	.67	2.00	**313.7**
9	.58	.50	.33	.60	.38	**109.4**	1.99	.90	2.17	**109.4**
10	**226.8**	.05	.17	.06	.01	.76	1.65	.78	2.07	**226.8**
11	.11	.06	.01	.18	**121.9**	.66	1.78	.71	2.13	**121.9**
12	**352.3**	.03	.27	.08	.05	.88	2.20	.85	2.16	**352.3**
13	.10	.05	**35.9**	.18	.02	.65	1.80	.71	2.16	**35.9**
14	.37	.13	**36.5**	.49	.21	.29	2.02	.82	2.25	**36.5**
15	56	.40	.09	.59	.30	**35.5**	2.02	.89	2.26	**35.5**
18	.30	.21	.31	.53	**269.7**	.99	1.93	.99	2.37	**269.7**
20	1.29	1.08	.77	1.31	.75	**105.5**	2.51	1.16	2.57	**105.5**
26	1.56	1.19	1.30	.98	.51	.31	1.35	**122.1**	.80	**122.1**
27	.77	1.02	1.67	**13.9**	.24	1.13	**16.1**	**43.8**	**8.2**	**82.0**
29	1.14	1.21	1.41	.38	.42	.75	.67	**310.0**	.09	**310.0**
Total Shipments†	**716.7**	**1,533.3**	**211.5**	**232.4**	**1,607.6**	**459.8**	**16.1**	**475.9**	**8.2**	**5,261.5**

*These may also be regarded as surplus consumption regions in relation to regional slaughter.

†Millions of pounds of carcass beef.

‡Bold face numbers are shipments of beef in millions of pounds carcass weight; remaining values represent additional transportation costs per unit (dollars per hundredweight or cents per pound) that would be incurred if a shipment were made between the pair of regions represented by a particular cell.

Source: Original data.

TABLE 11.—Beef and Pork: Price Differentials between Regions, Cents per Pound Retail, and Per Capita Consumption, Multiproduct Spatial Equilibrium Solutions, 29 Regions, United States, 1962.

Base Region = Region 17, Iowa

Region*	Pork: Slaughter-Consumption Multiproduct Solution — Base Region Price = 57.79		Beef: Slaughter Consumption Multiproduct Solution — Base Region Price = 74.51	
	Cents	Per Capita Consumption Pounds†	Cents	Per Capita Consumption Pounds†
1	2.40	54.77	2.36	97.57
2	1.94	55.67	1.92	99.30
3	2.10	54.69	2.10	97.08
4	1.94	55.28	1.93	98.35
5	1.59	55.35	1.87	97.82
6	1.44	71.43	2.00	61.72
7	1.47	71.17	1.53	61.82
8	2.02	71.02	1.90	62.16
9	2.49	70.08	1.99	60.84
10	1.40	69.44	1.37	109.48
11	0.91	69.88	1.20	109.66
12	1.20	69.79	1.17	110.13
13	0.68	70.30	1.03	110.38
14	0.96	71.88	1.10	62.95
15	1.69	71.04	1.29	62.31
16	−0.15	70.99	−0.18	111.84
17	0.00	70.84	0.00	111.58
18	0.36	70 55	0.51	110.98
19	0.44	70 47	0.13	111.49
20	1.75	70.82	0.67	62.76
21	0.01	70.71	−0.58	112.08
22	0.08	70.74	−0.47	112.16
23	1.52	71.17	0.23	64.25
24	1.40	56.11	0.25	118.08
25	1.05	56.77	−0.30	119.59
26	2.00	56.02	0.94	118.22
27	2.68	55.53	2.09	116.98
28	1.76	56.46	.44	119.40
29	2.86	55.35	1.89	117.23

*Regions identified in Table 1 and Fig. 1.

†Consumption in carcass weight equivalent. Beef column aggregates beef and veal.

of these meats would continue only through 1965 and that trend changes from 1965 to 1975 would continue at only half the earlier rate.

Two assumptions also were made regarding location of slaughter in 1975. One was that the regional distribution of slaughter for both cattle and hogs would be the same as in 1962. The second assumption was that all slaughter in 1975 would take place in the region where the livestock were produced. The three models, which represent combinations of the above assumptions, are basically:

1. Consumption assumption II, with the 1962 distribution of slaughter.
2. Consumption assumption II, with production-oriented slaughter.
3. Consumption assumption I, with production-oriented slaughter.

Eight separate solutions were obtained for 1975, including four pork solutions and four beef and veal solutions. Transportation models were used to obtain production-to-slaughter solutions for both cattle and hogs for assumption II assuming 1962 regional distribution of slaughter. Mutiproduct spatial equilibrium slaughter-to-consumption solutions were obtained for beef and pork, again under the same assumption. Finally, multiproduct production-to-consumption spatial equilibrium solutions were obtained for beef and pork under both assumptions I and II, assuming in both cases that slaughter was production oriented. These production-to-consumption models, however, are omitted from this presentation.

Consumption Estimates

Assumption I: U. S. average per capita consumption estimates for beef and pork in 1975 were based on estimates of annual percentage changes in consumption developed by Brandow.[15]

The Brandow estimates were applied to average per capita consumption (carcass weight) of beef, veal, and pork for 1948-62. For these years, average per capita consumption of pork was 65.85 pounds, beef 76.50 pounds and veal 7.81 pounds. By using 1955 as the midpoint and compounding the indicated percentage changes to 1975, per capita consumption was projected for 1975. This procedure yielded a 1975 per capita pork consumption estimate of 53.74 pounds (carcass weight), beef consumption estimate of 114.36 pounds, and veal consumption estimate of 7.75 pounds.

Assumption II: An alternate set of consumption projections was made, assuming some modifications of the expected influence of consumer preference changes. No modification was made in the projection for

[15]Brandow, G. E. op. cit.

veal. Applying these assumptions resulted in an estimate of 1975 per capita beef consumption of 106.94 pounds and pork consumption of 57.71 pounds (carcass weight).

The modification of annual trend changes on beef and pork consumption in assumption II is arbitrary but defensible on several points:

1. Population migration from East to West and from rural to urban areas is expected to continue but at a reduced rate, moderating the changes in consumption related to region and urbanization.

2. Quality improvement may moderate the decline in demand for pork.

3. Part of the increase in demand for beef in recent years has been attributed to the increased use of home refrigeration and home freezers, desirable display attributes for self-service meat retailing, and increased advertising and promotion of beef. Such factors may have already exerted their greatest influence on consumption patterns.

Based on these qualifications, assumption II has been employed in all but two of the 1975 spatial equilibrium and transportation model solutions.[16]

Population Projections

Populations for 1975 were derived from two published sources. U. S. total population for 1975 is from Bureau of Census Series III projections.[17] Regional projections were based on percentage changes in population by states from 1960-75 projected by the Kiplinger Washington Editors.[18] These percentage changes were applied to 1960 Bureau of Census state population estimates.[19]

Population projections for New York City and Philadelphia (included in region 3) were made by applying a weighted average of the

[16]Projections of 1975 per capita consumption of beef and pork by Resources for the Future, Inc., under various assumptions regarding total meat use and variety in meat consumption, are below the projected levels for beef used in this study and are higher than the projected levels of per capita pork consumption. Estimates by this organization for beef and veal combined range from as low as 93 pounds per capita to a high of 112 pounds, while pork consumption is projected in a range of 60 to 80 pounds per capita in 1975. Landsberg, H. H., L. L. Fischman, and J. L. Fisher. 1963. Resources in America's Future: Patterns of Requirements and Availabilities, 1960-2000. Published for Resources for the Future, Inc., by the Johns Hopkins Press, Baltimore.

[17]Bureau of the Census, U. S. Department of Commerce. 1962. Current Population Reports, Population Estimates. Series P-25, No. 251. The specific projections are the Series III projections (one of four series based on different assumptions in regard to fertility rates) which assume the fertility rate declines from the 1955-57 level to the 1949-57 level by 1965-70 and remains at that level to 1980. This is the third lowest of the four fertility rates used in Bureau of Census projections and therefore represents a 1975 population level intermediate between the high and low projected ranges, but tending to the low side.

[18]The Kiplinger Washington Editors. Dec. 23, 1961. The Big Growth Ahead (Special enclosure to The Kiplinger Washington Letter).

[19]Bureau of the Census, U. S. Department of Commerce. Statistical Abstract of the United States, 1961.

percentage change in population of New York, New Jersey, and Pennsylvania. The Ohio population for 1975 was allocated between regions 10 and 11 in the same proportions that existed in 1960 (54.7 percent to region 10).

Regional Production in 1975

Hogs: Estimated 1975 per capita consumption of pork multiplied by projected 1975 population in the continental United States was used as an estimate of aggregate consumption and production of pork in the United States, assuming that domestic consumption of pork would be equal to domestic production.[20]

The increase in total hog production from 1962 to 1975 under consumption assumption I would be only 2.5 percent. The somewhat higher per capita pork consumption under assumption II would require a 10 percent increase in pork production from 1962 to 1975.

Allocation of estimated 1975 hog production among the 29 regions was made largely on the basis of a subjective evaluation of changes in the regional distribution of hog production in recent years. Changes in regional shares of total hog production were examined for the periods from 1950-52 to 1960-62 and from 1940-42 to 1960-62. Major changes between these periods were a moderate increase in the proportion of hogs raised in the North Central States and a decline in the proportion produced in the South Central States. Decreases also occurred in the North Atlantic, Mountain, and Pacific Coast States (Table 12).

Specifically, it was estimated that regional shares of U. S. hog production between 1960-62 and 1975 would show these changes:

North Central States:	increase from	80.6	to	82.8	percent.
North Atlantic States:	decrease from	1.7	to	1.3	percent.
South Atlantic States:	increase from	6.3	to	6.5	percent.
South Central States:	decrease from	9.3	to	7.8	percent.
Mountain States:	decrease from	1.1	to	0.8	percent.
Pacific Coast States:	decrease from	1.0	to	0.8	percent.

Changes for states within these regional groupings were estimated on the basis of changes from 1950-52 to 1960-62, consistent with the overall regional changes estimated. Resulting estimates of hog production in the 1975 analysis are shown in Table 13.

Cattle and Calves for Slaughter: Projecting the regional distribution of 1975 production of slaughter cattle and calves presented problems similar to those encountered in estimating 1962 production on a state or regional basis. Published estimates are not available on annual

[20]A corollary assumption is that foreign trade in pork will remain insignificant and/or that exports and imports will cancel each other.

production of cattle and calves for slaughter by states. Beef production estimates used in this analysis represent an adjustment of published data on cattle and calf marketings to omit probable marketings of non-slaughter cattle and to add the volume of cattle slaughtered on farms (Appendix C).

Two alternative sets of data were examined to provide an indication of recent changes in beef production:[21]

1. Published data on annual liveweight production of cattle and calves, by states, adjusted for in-shipments and changes in inventory.

2. Published annual estimates of the number of cattle on feed for market as of January 1 in major cattle feeding states.

[21]The work of other researchers who have made more extensive studies of beef production trends served as guidlines for projections of future changes in slaughter beef production.

TABLE 12.—Hog Production, Percent of U. S. Total by Regions and Selected States, Averages 1940-42, 1950-52, and 1960-62.

Region	1940-42 Average	1950-52 Average	1960-62 Average	Change in Regional Share 1940-42 to 1960-62	Change in Regional Share 1950-52 to 1960-62
	Percent of U. S. Total			Percent	Percent
North Atlantic*	2.4	2.2	1.7	− .7	− .5
South Atlantic†	5.9	6.3	6.3	+ .4	0
North Central	75.2	77.9	80.6	+5.4	+2.7
East North Central‡	(30.7)	(30.2)	(32.6)	(+1.9)	(+2.4)
West North Central§	(44.5)	(47.7)	(48.0)	(+3.5)	(+ .3)
South Central**	12.4	11.0	9.3	− 3.1	−1.7
Mountain††	2.1	1.4	1.1	− 1.0	− .3
Pacific ‡‡	2.0	1.2	1.0	− 1.0	− .2
	100.0	100.0	100.0	0	0

*Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, Connecticut, New York, New Jersey, Pennsylvania, Delaware, Maryland, District of Columbia.

†Virginia, West Virginia, North Carolina, South Carolina, Georgia, Florida.

‡Ohio, Indiana, Illinois, Michigan, Wisconsin.

§Minnesota, Iowa, Missouri, South Dakota, North Dakota, Nebraska, Kansas.

**Kentucky, Tennessee, Alabama, Mississippi, Arkansas, Louisiana, Oklahoma, Texas.

††Montana, Idaho, Wyoming, Colorado, New Mexico, Arizona, Utah, Nevada.

‡‡Washington, Oregon, California

Sources: U. S. Department of Agriculture. 1963. Meat Animals, Farm Production, Disposition and Income by States, 1961-62. Mt. An. (63). U. S. Department of Agriculture. 1956. Meat Animals, Farm Production, Disposition and Income by States, 1950-54, Stat. Bull. 184. U. S. Department of Agriculture 1947. Meat Animals, Farm Production and Income, 1924-44.

TABLE 13.—Hog Production, Hog Slaughter, and Pork Production, 29 Regions, United States, Consumption Assumption II, Projected 1975.

Region	State	Hog Production* 1,000 Lbs. Liveweight	Hog Slaughter† 1,000 Lbs. Liveweight	Pork Production‡ 1,000 Lbs. Carcass Weight	Pork Production (Slaughter)§ 1,000 Lbs. Carcass Weight
1	Mass., Conn., R.I., Me., Vt., N.H.	39,667	174,092	23,473	103,019
2	N.Y. (N.Y.C. excluded)	30,851	370,219	18,256	219,077
3	N.J., N.Y.C., Phila.	26,444	328,350	15,648	194,301
4	Md., Del., D.C.	59,500	167,479	35,209	99,106
5	Pa. (Phila. excluded)	134,425	740,439	79,546	438,155
6	Virginia	200,535	588,385	118,667	348,177
7	West Virginia	24,240	48,482	14,344	28,689
8	N.C., S.C., Ga.	1,119,474	1,015,900	662,449	601,159
9	Florida	83,740	145,443	49,553	86,066
10	Eastern Ohio	169,685	473,793	100,411	280,367
11	Western Ohio	727,217	592,792	430,331	350,785
12	Michigan	264,442	451,756	156,484	267,327
13	Indiana	2,128,761	1,401,545	1,259,695	829,365
14	Kentucky, Tenn.	974,029	1,106,250	576,382	654,624
15	Alabama, Miss.	414,293	434,126	245,158	256,894
16	Minnesota, Wisc.	2,287,427	2,448,296	1,353,586	1,448,780
17	Iowa	5,077,294	3,955,617	3,004,491	2,340,738
18	Illinois	3,484,030	1,595,468	2,061,676	944,119
19	Missouri	1,566,821	1,130,492	927,167	668,969
20	Ark., La.	99,165	178,499	58,681	105,627
21	N. Dakota, S. Dakota	938,771	744,846	555,518	440,763
22	Nebraska, Kansas	1,569,025	2,051,632	928,471	1,214,054
23	Oklahoma, Texas	249,017	687,550	147,356	406,858
24	Mont., Idaho, Wyo.	99,165	127,814	58,681	75,634
25	Colorado	50,685	174,092	29,993	103,019
26	N. Mexico, Ariz.	26,444	66,111	15,648	39,121
27	Washington, Ore.	110,185	308,515	65,202	182,564
28	Nevada, Utah	22,036	74,925	13,040	44,337
29	California	59,500	453,960	35,209	268,631
	United States	22,036,868	22,036,868	13,040,325	13,040,325

*Projected 1975 regional hog production under consumption assumption II, liveweight.

†Projected 1975, regional slaughter, assuming the 1962 regional distribution of slaughter, liveweight.

‡Production of carcass pork, based on a conversion factor of 59.175039 percent from liveweight to carcass.

§Hog slaughter, liveweight; converted to carcass weight by factor of 59.175039 percent

Source: Original data.

TABLE 14.—Cattle and Calf Production, Percent of U. S. Total, by Regions, Averages 1940-52, 1950-52, and 1960-62.

Region	1940-42 Average	1950-52 Average	1960-62 Average	Change in Regional Share: 1940-42 to 1960-62	Change in Regional Share: 1950-52 to 1960-62
	Percent of U. S. Total			Percent	Percent
North Atlantic*	5.3	5.3	4.0	−1.3	−1.3
South Atlantic†	3.9	4.5	5.0	+1.1	+ .5
North Central	53.0	49.4	48.4	−4.6	−1.0
East North Central‡	(17.3)	(15.5)	(13.8)	(−3.5)	(−1.7)
West North Central§	(35.7)	(33.8)	(34.6)	(−1.1)	(+ .8)
South Central**	20.9	22.1	23.1	+2.2	+1.0
Mountain††	10.9	12.0	11.9	+1.0	− .1
Pacific‡‡	6.0	6.7	7.6	+1.6	+ .9
	100.0	100.0	100.0	0	0

*Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, Connecticut, New York, New Jersey, Pennsylvania, Delaware, Maryland, District of Columbia.

†Virginia, West Virginia, North Carolina, South Carolina, Georgia, Florida.

‡Ohio, Indiana, Illinois, Michigan, Wisconsin.

§Minnesota, Iowa, Missouri, South Dakota, North Dakota, Nebraska, Kansas.

**Kentucky, Tennessee, Alabama, Mississippi, Arkansas, Louisiana, Oklahoma, Texas.

††Montana, Idaho, Wyoming, Colorado, New Mexico, Arizona, Utah, Nevada.

‡‡Washington, Oregon, California.

Sources: U. S. Department of Agriculture. 1963. Meat Animals, Farm Production, Disposition and Income by States, 1961-62, Mt. An. (63). U. S. Department of Agriculture. 1956. Meat Animals, Farm Production, Disposition and Income by States, 1950-54, Stat. Bull. 184. U. S. Department of Agriculture. 1947. Meat Animals, Farm Production and Income, 1924-44.

Changes in these data do not necessarily coincide, however, with changes in the aggregate volume of cattle and calves fed to slaughter conditions.

Changes in the regional distribution of total liveweight cattle and calf production from 1940-42 and 1950-52 to 1960-62 appear in Table 14. Minor changes are indicated in the distribution of cattle production, especially between the 1950-52 and 1960-62 periods.

More substantial changes have taken place in the regional distribution of cattle and calves grain-fed for market. Changes from 1950-52 to 1960-62 appear in Table 15.

Major changes were a decline of nearly 7 percent in the proportion of total cattle and calves on feed in the North Central States and an 8 percent increase in the proportion of cattle on feed in the Western States. Data on the number of cattle on feed in the South Atlantic States was

TABLE 15.—Cattle on Feed January 1, Regional Distribution of Number on Feed in 26 Major Feeding States, Averages 1950-52, 1955-57, and 1960-62.

Region or State	Percent of Total			Change in Regional Share 1950-52 to 1960-62
	1950-52 Average	1955-57 Average	1960-62 Average	
				Percent
Pennsylvania	1.93	1.44	1.15	−0.78
North Central States	74.47	72.07	67.56	−6.91
East North Central	(21.30)	(22.80)	(18.07)	(−3.23)
West North Central	(53.17)	(49.27)	(49.49)	(−3.68)
Oklahoma	1.24	1.12	1.06	−0.18
Texas	3.77	2.45	3.62	−0.15
Western States	18.59	22.92	26.61	+8.02
	100.00	100.00	100.00	0

Sources: U. S. Department of Agriculture. 1956. Cattle and Calves on Feed. AMS 147. U. S. Department of Agriculture, Agricultural Statistics. (1957, 1958 and 1961 editions). U. S. Department of Agriculture. 1963. Livestock and Meat Statistics 1962, Stat. Bull. 333.

not available prior to 1960. Although indications are that the number of cattle grain-fed has increased in these areas during recent years, the areas displayed little change in the proportion of cattle fed from 1960 to 1963.

The increase in cattle feeding in the Western States was most rapid during the early and mid-1950's. The past 5 years appear to have brought relatively small change in the regional distribution of cattle feeding. This has led to forecasts that future changes and shifts in cattle feeding and production will be considerably more gradual than changes during the 1950-1960 decade.[22]

The total level of U. S. beef and veal production in 1975 projected under consumption assumption I was 26.2 billion pounds carcass weight; under consumption assumption II, 24.6 billion pounds. These represent increases of 61 percent and 51 percent from actual 1962 beef and veal production. By comparison, U. S. beef and veal production increased 47 percent between 1950 and 1960.

[22]Dunbar, John O. 1963. Changing Beef Patterns and Land Use. The Future for Beef. Center for Agricultural and Economic Adjustment, Iowa State University. CAEA Report 15. Also see Dean, C. W. and C. O. McCorkle, Jr. 1961. Projections Relating to California Agriculture in 1975. California Agricultural Experiment Station. Bull 778.

Specific changes projected for 1975 compared with those for 1962 in distribution of slaughter cattle and calf production among major geographic regions were as follows:

North Atlantic States:	decrease	from	4.7	to	3.3 percent.
South Atlantic States:	increase	from	2.6	to	2.9 percent.
North Central States:	decrease	from	59.2	to	57.2 percent.
South Central States:	increase	from	12.8	to	13.7 percent.
Western States:	increase	from	20.7	to	22.9 percent.

Regional estimates of cattle and calf production in the 1975 analysis are summarized in Table 16.

Slaughter Locations in 1975

Two alternate assumptions were made in regard to 1975 slaughter locations for beef and pork. One assumption was that the regional distribution of total slaughter in 1975 would be unchanged from the 1962 distribution for both hogs and cattle and calves. Thus, regions would share the increase in slaughter activity in proportion to their 1962 share of total slaughter.

The alternative assumption was that 1975 slaughter of hogs, cattle and calves would take place completely within the regions where they were produced. The assumption of wholly production-oriented slaughter in 1975 is not presented as a likely development. Though analytically of some value, it is not employed in this presentation.

Income Projections

A projected increase of 38 percent in U. S. average per capita disposable income between 1960 and 1975, derived from projections made by Resources for the Future, Inc., was used in estimating average income change.[23] Regional projections were developed on the basis of ratio relationships. Percentage changes in per capita personal income between 1947 and 1962, by states, were converted to ratios of the percentage change that occurred in U. S. average per capita personal income from 1947-62. These ratios of state to national per capita income change were aggregated to represent the regional demarcation employed in this study.

Regional to U. S. ratios of per capita personal income change were applied to the 38 percent increase in disposable income per capita projected for the United States, deriving estimates of percentage change in regional income per capita. This procedure projected regional per capita disposable income changes for 1960-75 in the same relationship to

[23]Landsberg, H. H. et al. op. cit.

TABLE 16.—Cattle and Calf Production for Slaughter, Cattle and Calf Slaughter, and Beef and Veal Production, 29 Regions, United States, Consumption Assumption II, Projected 1975.

Region	State	Cattle and Calf Production* 1,000 Lbs. Liveweight	Cattle and Calf Slaughter† 1,000 Lbs. Liveweight	Beef and Veal Production‡ 1,000 Lbs. Carcass Weight	Beef and Veal Production (Slaughter)§ 1,000 Lbs. Carcass Weight
1	Mass., Conn., R.I., Me., Vt., N.H.	247,498	425,522	140,391	241,374
2	N.Y. (N.Y.C. excluded)	412,496	994,331	233,985	564,026
3	N.J., N.Y.C., Phila.	69,473	924,858	39,408	524,618
4	Md., Del., D.C.	178,025	238,814	100,983	135,465
5	Pa. (Phila. excluded)	538,416	1,628,273	305,412	923,624
6	Virginia	382,102	373,418	216,744	211,818
7	West Virginia	130,262	112,894	73,890	64,038
8	N.C., S.C., Ga.	607,889	903,148	344,820	512,303
9	Florida	138,946	534,074	78,816	302,949
10	Eastern Ohio	334,339	898,806	189,651	509,840
11	Western Ohio	686,045	916,174	389,153	519,692
12	Michigan	664,334	1,246,171	376,838	706,880
13	Indiana	742,492	1,198,408	421,172	679,787
14	Kentucky, Tenn.	1,159,330	950,912	657,620	539,396
15	Alabama, Mississippi	838,017	772,886	475,358	438,413
16	Minnesota, Wisconsin	3,864,433	4,012,064	2,192,067	2,275,809
17	Iowa	5,332,050	4,854,423	3,024,560	2,753,630
18	Illinois	2,765,893	2,075,504	1,568,929	1,177,312
19	Missouri	1,563,142	1,767,219	886,679	1,002,440
20	Ark., La.	486,311	521,048	275,856	295,560
21	N. Dakota, S. Dakota	1,849,718	998,673	1,049,237	566,489
22	Nebraska, Kansas	5,918,227	5,314,681	3,357,064	3,014,708
23	Oklahoma, Texas	4,572,188	3,230,492	2,593,535	1,832,469
24	Mont., Idaho, Wyo.	1,333,013	564,469	756,140	320,190
25	Colorado	1,949,584	1,832,350	1,105,885	1,039,385
26	N. Mexico, Arizona	1,706,430	416,838	967,958	236,448
27	Washington, Ore.	959,595	1,194,066	544,322	677,324
28	Nevada, Utah	295,260	408,154	167,484	231,522
29	California	3,695,093	4,111,931	2,096,010	2,332,458
	United States	43,420,601	43,420,601	24,629,967	24,629,967

*Projected 1975 regional cattle and calf production for slaughter under consumption assumption II, liveweight.

†Projected 1975 regional slaughter assuming the 1962 regional distribution of slaughter, liveweight.

‡Production of carcass beef and veal, based on a conversion factor of 56.72415 percent from liveweight to carcass weight.

§Cattle and calf slaughter, liveweight, converted to carcass weight by factor of 56.72415 percent.

Source: Original data.

the change in U. S. average per capita disposable income that occurred in the 1947-62 period.

Transportation Rates

Transportation costs between regions for the 1975 analysis were obtained from the same functional relationship between rates and highway mileages used in the 1962 solutions. Percentage increases in these rates to 1975 were derived from time series analysis of the index of rail freight rates on livestock and meat for the years 1948-1960, completed in previous research.[24]

Equation for projected live transportation rates:

$Yh_t = 91.33 + 1.23846X$

where:

Yh_t = transportation rate for live animals in year t as a percent of 1960

X = appropriate time series value (number of years since 1954, the midpoint of the time period used)

Equation for projected meat transportation rates:

$Ym_t = 109.70 + .24725X$

where:

Ym_t = transportation rate for meat in year t as a percent of 1960

X = appropriate time series value (number of years since 1954, the midpoint of the time period used)

Rate increase indexes obtained from the above equation were:

$Yh_{1975} = 91.33 + 1.23846\ (21) = 117.34$

$Ym_{1975} = 109.70 + .24725\ (21) = 114.89$

Regional Demand Functions

The set of regional demand functions used in the 1975 analysis were of the same form as those used with the 1962 multiproduct spatial equilibrium models and discussed in detail in Appendixes A and D. Coefficients used were identical to those applied in the 1962 analysis. Vertical intercepts (and levels) for regional demand functions were adjusted to reflect trend effects assumed in projecting per capita consumption of beef and pork for 1975. Vertical intercepts employed in the 1975 models, under both consumption assumptions I and II, are presented in Table 6.

Equilibrium prices and regional demands for beef and pork were estimated initially from transportation models for beef and pork. Price

[24]Stout, Thomas T., Ernest R. Bentley, and Francis E. Walker. op. cit. Appendix Table 4. In deflating the series to arrive at an estimated value in constant dollars, the B.L.S. Wholesale Price Index was employed. This recognized that inflation of a service charge by an index of commodity prices serves at best as only a general indicator of changes in real dollars.

differentials obtained in subsequent iterations were incorporated in the computation of revised base region prices for both beef and pork, regional demands were recomputed, and optimum distribution patterns obtained. This iterative process continued on both products until successive iterations yielded identical price differentials, indicating a simultaneous equilibrium condition for both beef and pork in respect to regional prices and quantities.

OPTIMUM INTERREGIONAL TRADE PATTERNS FOR 1975

Eight optimum trade patterns were derived for cattle, hogs, beef, and pork under projected 1975 conditions of production, slaughter, and consumption. Four are presented in this publication:[25] optimum production-to-slaughter shipment patterns for cattle and hogs and optimum slaughter-to-consumption patterns for beef and for pork, assuming the 1962 percentage distribution of regional slaughter under consumption assumption II conditions.

Production-to-Slaughter Shipments (Transportation Models)

Hogs: The regional distribution of slaughter was unchanged from 1962. The optimum shipment pattern of slaughter hogs to deficit regions is presented in Table 17. Western Ohio (region 11) remained surplus in production relative to slaughter and Eastern Ohio (region 10) remained deficit. The relative status of both regions therefore remained unchanged from the 1962 situation. However, region 8 (North Carolina-South Carolina-Georgia), a deficit producer in 1962, evolved as a surplus region in 1975. Three other regions shifted from surplus to deficit producers in the same period. These were region 15 (Alabama-Mississippi), region 20 (Arkansas-Louisiana), and region 24 (Montana-Wyoming-Idaho).

The slaughter hog export pattern for Western Ohio located destinations in regions 4 and 5 (Maryland-Delaware-D.C. and Pennsylvania) and indicated potential and probable markets in New Jersey and West Virginia. At a small additional cost, market possibilities existed in Virginia, the New England states, and Eastern Ohio. However, the optimum procurement source for Eastern Ohio was Illinois (region 18), with Western Ohio and Indiana (region 13) alternative procurement sources under somewhat higher cost conditions.

Surplus regions west of the Mississippi River shipped predominantly to the West, while surplus regions in the Eastern Corn Belt exported live

[25]Models omitted from this presentation were production-to-consumption shipment patterns for beef and pork, presented alternatively under each consumption assumption. Details of these analyses may be obtained from the authors.

TABLE 17.—Pork Transportation Model, Production to Slaughter: Optimum Shipment Pattern for Hogs, Surplus Production Regions to Surplus Slaughter Regions, 29 Regions, United States, Projected 1975 (Transportation Cost — $61,019,552).

Deficit Production Region*	Surplus Hog Production Regions							Total Destination Requirements†
	8	11	13	17	18	19	21	
	Volume of Shipments and Non-Optimal Cost Coefficients‡							
1	.46	.05	.06	.55	**134.4**	.51	1.68	**134.4**
2	.87	.26	.22	.53	**339.4**	.56	1.65	**339.4**
3	.42	.01	.01	.52	**301.9**	.42	1.73	**301.9**
4	.35	**108.0**	.01	.59	.02	.50	1.74	**108.0**
5	.50	**26.4**	**357.0**	.57	**222.6**	.47	1.73	**606.0**
6	**41.9**	.03	**346.0**	.64	.03	.45	1.80	**387.9**
7	.50	.01	**24.2**	.74	.04	.46	1.85	**24.2**
9	**61.7**	.58	.44	.88	.31	.55	2.28	**61.7**
10	.97	.06	.06	.54	**304.1**	.55	1.66	**304.1**
12	1.37	31	.18	.51	**187.3**	.64	1.64	**187.3**
14	.87	.30	.09	.45	**132.2**	.22	1.93	**132.2**
15	.30	.39	.15	.55	**19.8**	.10	1.90	**19.8**
16	1.88	.91	.59	**160.9**	.02	.33	.54	**160.9**
20	.84	.67	.13	.45	**79.3**	.02	1.86	**79.3**
22	2.04	1.07	.75	**317.3**	**165.3**	.28	.62	**482.6**
23	1.11	.80	.47	.02	**2.2**	**436.3**	.98	**438.5**
24	2.15	1.19	.88	**28.7**	.18	.48	.10	**28.7**
25	1.92	1.00	.67	**123.4**	.14	.36	.65	**123.4**
26	1.53	.89	.74	**39.7**	.04	.01	.83	**39.7**
27	2.08	1.15	.83	**4.4**	.16	.67	**193.9**	**198.3**
28	2.03	1.11	.78	**52.9**	.16	.55	.33	**52.9**
29	1.81	96	.65	**394.5**	.15	.09	.19	**394.5**
Total Shipments†	**103.6**	**134.4**	**727.2**	**1,121.8**	**1,888.5**	**436.3**	**193.9**	**4,605.7**

*These may also be regarded as surplus slaughter regions in relation to regional hog production.

†Millions of pounds liveweight.

‡Bold face numbers are hog shipments in millions of pounds liveweight; remaining numbers represent additional transportation costs per unit (dollars per hundredweight or cents per pound) that would be incurred if a shipment were made between the pair of regions represented by a particular cell.

Source: Original data

hogs to the East and South. Region 8 (North Carolina-South Carolina-Georgia) replaced regions 18, 15, and 20 (Illinois, Alabama-Mississippi, Arkansas-Louisiana) as exporters to region 9 (Florida) in the 1975 solution.

Cattle and Calves: The optimum shipment pattern for live cattle and calves from surplus production regions to deficit regions relative to slaughter is presented in Table 18. The alignment of surplus and deficit regions showed some change between 1962 and 1975. Both regions 6 (Virginia) and 15 (Alabama-Mississippi) moved from deficit to surplus production positions, reflecting an increase in regional production shares without a corresponding increase in slaughter activity.

In 1975, both Eastern and Western Ohio continued as deficit production regions relative to local slaughter capacity. However, supply sources for the two regions showed some shift from 1962. Eastern Ohio imported live cattle and calves for slaughter from region 22 (Kansas-Nebraska) and region 26 (Arizona-New Mexico), while 1962 requirements were imported from region 22 (Kansas-Nebraska) and region 24 (Montana-Wyoming-Idaho). Regions 21 (North and South Dakota), 17 (Iowa), 18 (Illinois), and 24 (Montana-Wyoming-Idaho) were other potential supply sources at somewhat higher total cost.

Western Ohio obtained its slaughter requirements from region 26 (Arizona-New Mexico), with no other favorable alternatives indicated in the optimum solution. Imports of cattle and calves from nearby regions would occur only during short-term disequilibrium periods.

In general, the 1975 solutions indicated a larger movement of cattle from the Southwest to eastern slaughter locations, as well as an increase in slaughter cattle in the Virginia-West Virginia area.

Slaughter-to-Consumption Shipments (Multiproduct Spatial Equilibrium Models)

Pork: Regional consumption requirements for slaughter-consumption shipment estimates were developed from a set of regional demand functions included in the multiproduct beef and pork spatial equilibrium model.

Prices of both beef and pork were permitted to vary simultaneously within regions until an equilibrium condition was derived. Equilibrium price-quantity relationships were established through successive iterations of both pork and beef data until each yielded identical price differentials in successive iterations, as in the 1962 analysis. Consumption assumption II was used as the basis for aggregate slaughter and consumption of pork. The regional percentage distribution of hog slaughter observed in 1962 was left unchanged.

TABLE 18.—Beef Transportation Model, Production to Slaughter: Optimum Shipment Pattern for Cattle and Calves, Surplus Production Regions to Surplus Slaughter Regions, 29 Regions, United States, Projected 1975 (Transportation Cost — $132,304,579).

Deficit Production Region*	Surplus Cattle and Calf Production Regions												Total Destination Requirements†
	6	7	14	15	17	18	21	22	23	24	25	26	
	Volume of Shipments and Non-Optimal Cost Coefficients‡												
1	.03	.05	.06	.10	.03	**104.2**	**73.8**	.01	.05	.96	.12	.14	**178.0**
2	.48	.39	.39	.45	.04	.03	**581.8**	.19	.28	26	.48	.34	**581.8**
3	**8.7**	.07	.01	.06	**477.6**	**369.1**	.05	.04	.01	.08	.03	.08	**855.4**
4	0	.06	**60.8**	.06	.14	.09	.13	.13	.01	.17	.09	.17	**60.8**
5	.09	**17.4**	**147.6**	.01	.05	**217.1**	.03	**364.8**	**343.0**	.10	.04	.07	**1,089.9**
8	1.02	.56	.45	**65.1**	.92	.84	.98	.87	**230.1**	1.02	.78	.26	**295.2**
9	1.75	1.45	.72	.17	1.30	1.25	1.54	1.33	**395.1**	1.54	1.12	.44	**395.1**
10	.91	.31	.21	45	.08	.06	.04	**238.8**	.14	06	.11	**325.7**	**564.5**
11	1.39	.53	.19	.49	.26	.18	.32	.18	.16	.23	.16	**230.1**	**230.1**
12	1.37	.77	.31	.65	.03	.04	**47.8**	.01	.22	**534.1**	.12	.22	**581.8**
13	1.54	.72	.16	.46	.17	.07	.16	.03	**388.7**	.20	**117.2**	.05	**455.9**
16	3.19	2.38	1.77	1.93	.62	1.16	**147.6**	.53	.97	.20	.52	.88	**147.6**
19	2.68	1.85	1.04	1.08	.48	.79	.72	.30	.26	.58	.19	**204.1**	**204.1**
20	3.21	2.54	1.66	1.15	1.84	1.91	2.09	1.46	**34.8**	1.68	1.13	.43	**34.8**
27	5.72	4.84	4.09	4.17	2.83	3.51	1.67	1.95	2.25	**234.5**	.96	.37	**234.5**
28	5.38	4.54	3.80	3.84	2.56	3.24	1.73	1.65	1.83	.46	.63	**112.9**	**112.9**
29	5.97	5.09	4.38	3.76	3.28	3.95	2.55	2.39	2.07	.88	1.22	**416.8**	**416.8**
Total Shipments†	**8.7**	**17.4**	**208.4**	**65.1**	**477.6**	**690.4**	**851.0**	**603.4**	**1,341.7**	**768.6**	**117.2**	**1,289.6**	**6,439.3**

*These may also be regarded as surplus slaughter regions in relation to regional cattle and calf production for slaughter.

†Millions of pounds liveweight.

‡Bold face numbers are cattle and calf shipments in millions of pounds liveweight; remaining numbers represent additional transportation costs per unit (dollars per hundredweight or cents per pound) that would be incurred if a shipment were made between the pair of regions represented by a particular cell.

Source: Original data.

The optimum shipment pattern for carcass pork from surplus slaughter regions to deficit slaughter regions (surplus consumption regions) is shown in Table 19. The only change in the regional alignment of surplus and deficit regions between 1962 and 1975 was a shift in Western Ohio's position from a balance in slaughter and consumption in 1962 to a deficit slaughter position relative to consumption in 1975. Eastern Ohio remained a deficit region for slaughter in relation to regional consumption.

The optimum solution showed region 10 (Eastern Ohio) obtaining pork from region 13 (Indiana), region 16 (Minnesota-Wisconsin), and region 18 (Illinois). Region 17 (Iowa) was a fourth alternative at a slight additional cost. Region 11 (Western Ohio) imported the small quantity of pork it required from region 13 (Indiana) and had no other favorable supply alternatives.

Several changes occurred in the optimum shipment pattern for 1975. Region 13 (Indiana)) no longer shipped pork to region 8 (North Carolina-South Carolina-Georgia) but shipped instead to both Eastern and Western Ohio as indicated. Region 14 (Kentucky-Tennessee), previously an exporter to region 15 (Alabama-Mississippi), shipped to region 9 (Florida) as well. Region 17 (Iowa) did not ship to region 20 (Arkansas-Louisiana) in the 1975 solution but added shipments to region 26 (Arizona-New Mexico).

Region 11 (Western Ohio) and region 8 (North Carolina-South Carolina-Georgia), which were surplus in hog production relative to slaughter, imported carcass pork in the slaughter-to-consumption solution. Several regions imported live hogs and exported carcass pork. These included regions 5 (Pennsylvania), 6 (Virginia), 14 (Kentucky-Tennessee), 16 (Minnesota-Wisconsin), and 22 (Kansas-Nebraska). Regional prices and per capita consumption estimates derived from the solution for 1975 are presented in Table 21.

Beef: Regional consumption of domestically produced beef and veal for the 1975 slaughter-to-consumption solution was estimated from the regional demand functions in the multiproduct spatial equilibrium model for beef and pork.

The optimum shipment pattern for carcass beef and veal from surplus slaughter regions to deficit slaughter regions is presented in Table 20. Regions 14 (Kentucky-Tennessee) and 15 (Alabama-Mississippi), which were deficit slaughter regions in relation to consumption in 1962, were both surplus regions in the 1975 solution. The slaughter distribution assumption thus provided for a greater increase in regional slaughter than in consumption of beef and veal. The surplus-deficit status of other regions remained the same as in 1962.

TABLE 19.—Pork Multiproduct Spatial Equilibrium, Slaughter to Consumption: Optimum Shipment Pattern for Pork, Surplus Slaughter Regions to Surplus Consumption Regions, 29 Region Model, United States, Projected 1975, Consumption Assumption II (Transportation Cost — $125,021,867).

Deficit Slaughter Area*	Surplus Slaughter Region										Total Destination Requirements†
	5	6	13	14	16	17	18	19	21	22	
	Volume of Shipments and Non-Optimal Cost Coefficients‡										
1	.13	.26	.12	.55	**519.3**	.02	.07	40	78	.73	**519.3**
2	.39	.66	.26	.95	.19	**129.7**	.04	44	80	.92	**129.7**
3	**18.8**	.15	.03	.58	.06	**1,075.4**	.03	31	86	.78	**1,094.2**
4	.05	**34.1**	**172.2**	.48	.07	.07	.06	.38	89	.82	**206.3**
7	1.19	.76	.88	.35	.15	.17	**68.5**	.28	.99	.78	**68.5**
8	1.02	.37	**178.9**	.13	.18	.11	.08	.19	.98	.82	**178.9**
9	1.34	.73	.14	**202.2**	.13	**295.0**	.02	.09	.94	.64	**497.2**
10	1.13	1.18	**88.8**	.70	**17.6**	.02	**53.3**	.44	.86	.76	**159.7**
11	1.80	1.79	**13.9**	.70	.33	.24	.14	.46	1.20	.95	**13.9**
12	1.82	1.85	.13	.99	**311.0**	**70.5**	.01	56	.88	.80	**381.5**
15	1.87	1.44	20	**9.3**	.29	.07	.08	**91.3**	1.12	.74	**100.6**
20	2.51	2.11	.50	.41	.35	.07	.17	**261.1**	1.16	.47	**261.1**
23	3.11	2.74	1.13	1.10	.32	**572.9**	.61	.38	.81	.14	**572.9**
24	3.75	3.70	1.96	2.59	.21	.33	1.20	1.36	**25.9**	.36	**25.9**
25	2.77	3.68	1.72	2.23	.46	.30	1.14	.88	.72	**26.8**	**26.8**
26	3.26	3.01	1.41	1.21	.46	**12.6**	.67	.40	.58	**151.1**	**163.7**
27	3.34	3.24	1.69	2.12	.09	.34	1.07	1.37	**106.5**	.23	**106.5**
28	3.56	3.47	1.72	2.20	.38	.24	1.05	1.32	.22	**42.0**	**42.0**
29	3.01	2.91	1.73	1.78	.39	.13	.85	.64	**224.1**	**741.9**	**966.0**
Total Shipments†	**19.8**	**34.1**	**453.8**	**211.5**	**847.9**	**2,156.1**	**121.8**	**352.4**	**356.5**	**961.8**	**5,514.7**

*These may also be regarded as surplus consumption areas in relation to regional pork slaughter.

†Millions of pounds of carcass pork.

‡Bold face numbers are pork shipments in millions of pounds carcass weight; remaining values represent additional transportation costs per unit (dollars per hundredweight or cents per pound) that would be incurred if a shipment were made between the pair of regions represented by the particular cell

Source: Original data

TABLE 20.—Beef Multiproduct Spatial Equilibrium, Slaughter to Consumption: Optimum Shipment Pattern for Beef, Surplus Slaughter Regions to Surplus Consumption Regions, 29 Regions, United States, Projected 1975, Consumption Assumption II (Transportation Cost — $195,480,167).

Deficit Slaughter Region*	Surplus Slaughter Region											Total Destination Requirements†
	14	15	16	17	19	21	22	23	24	25	28	
	Volume of Shipments and Non-Optimal Cost Coefficients‡											
1	.53	.98	.02	.07	.17	.03	**1,159.6**	.78	2.20	1.21	2.45	**1,159.6**
2	.78	1.25	.16	**177.1**	.16	**40.8**	.14	.99	1.91	1.53	2.68	**217.9**
3	.41	89	.03	**2,210.5**	.03	.06	**159.0**	.76	1.76	1.17	2.54	**2,369.5**
4	.27	.75	**126.1**	.03	.06	.05	**422.8**	.68	1.78	1.15	2.55	**548.9**
5	.38	.86	.03	.04	.07	.08	**8.9**	.77	1.83	1.20	2.60	**8.9**
6	**55.7**	.49	.09	.09	.03	.12	**70.7**	.44	1.84	1.23	2.57	**126.4**
7	.18	.59	.12	.17	**15.1**	.19	**26.6**	.52	1.98	1.30	2.70	**41.7**
8	.05	**45.0**	.24	.20	**291.7**	.27	.13	.10	1.98	1.23	2.64	**336.7**
9	.31	.12	.58	.48	.29	.62	.34	**336.6**	2.22	1.40	2.73	**336.6**
10	.56	1.26	**369.9**	.05	.19	.09	.01	.97	1.92	1.34	2.71	**369.9**
11	.36	1.12	.13	.07	.01	.23	**206.6**	.86	1.97	1.27	2.78	**206.6**
12	.85	1.52	**589.0**	.03	.31	.11	.05	1.10	2.24	1.43	2.81	**589.0**
13	.46	1.25	.13	.06	**64.4**	.24	.03	.85	2.10	1.27	2.82	**64.4**
18	1.34	2.03	.35	.24	.35	.63	**456.1**	1.23	2.24	1.59	3.05	**456.1**
20	1.31	1.23	1.39	1.14	.79	1.43	.76	**110.5**	2.81	1.69	3.19	**110.5**
26	.96	2.60	1.35	.92	1.04	.70	.14	**284.3**	1.13	**19.8**	.83	**304.1**
27	2.75	3.18	.86	1.14	1.89	**47.6**	.25	1.37	**49.8**	.43	.31	**97.4**
29	2.41	2.24	.86	.93	1.16	**309.9**	.02	.52	.36	**675.4**	**1.0**	**986.3**
Total Shipments†	**55.7**	**45.0**	**1,085.0**	**2,387.6**	**371.2**	**398.3**	**2,510.3**	**731.4**	**49.8**	**695.2**	**1.0**	**8,330.5**

*These may also be regarded as surplus consumption areas in relation to beef slaughter.

†Millions of pounds of carcass beef.

‡Bold face numbers are shipments of carcass beef and veal in millions of pounds, carcass weight; remaining values represent additional transportation costs per unit (dollars per hundredweight or cents per pound) that would be incurred if a shipment were made between the pair of regions represented by the particular cell.

Source: Original data.

Region 10 (Eastern Ohio) remained a deficit region in slaughter relative to consumption, with the deficit obtained from region 16 (Minnesota-Wisconsin). Alternative sources included region 22 (Kansas-Nebraska) and region 17 (Iowa) at a small additional cost.

Region 11 (Western Ohio) was also deficit in beef in relation to slaughter in 1975 and imported from region 22 (Kansas-Nebraska). Region 19 (Missouri) could supply Western Ohio at only a slight competitive disadvantage and region 17 (Iowa) was a potential supplier at a small additional cost.

Numerous changes occurred in the 1975 shipment pattern compared with 1962. Region 17 (Iowa), a previous shipper to only region 3 (New Jersey-New York City-Philadelphia), exported to both region 3 and region 2 (New York). Region 19 (Missouri) no longer shipped to region 14 (Kentucky-Tennessee) and region 21 (North and South Dakota) no longer shipped to region 1 (New England). Region 23 (Oklahoma-Texas) lost shipments to regions 8 (North Carolina-South Carolina-Georgia) and 15 (Alabama-Mississippi) in the 1975 solution but added shipments to region 26 (Arizona-New Mexico).

A comparison of production-to-slaughter and slaughter-to-consumption solutions showed regions 6 (Virginia), 7 (West Virginia), 18 (Illinois), and 26 (Arizona-New Mexico) to be surplus producers of slaughter cattle and calves but deficit in slaughter relative to beef and veal consumption. This resulted in out-shipments of live cattle and calves and in-shipments of beef for consumption. By contrast, regions 16 (Minnesota-Wisconsin), 19 (Missouri), and 28 (Nevada-Utah) imported live cattle and calves for slaughter and exported carcass beef and veal to other regions. Equilibrium prices and per capita consumption estimates appear in Table 21.

TABLE 21.—Beef and Pork: Price Differentials between Regions, Cents per Pound Retail, and Per Capita Consumption, Multiproduct Spatial Equilibrium Solutions, 29 Regions, United States 1975.

(Base Region = Region 17, Iowa)

Region	Pork: Slaughter-Consumption Multiproduct Solution Assumption II		Beef: Slaughter-Consumption Multiproduct Solution Assumption II	
	Base Region Price = 57.78		Base Region Price = 76.72	
	Cents	Per Capita Consumption Pounds†	Cents	Per Capita Consumption Pounds†
1	2.76	49.47	2.71	117.19
2	2.23	49.87	2.23	117.65
3	2.41	49.74	2.41	117.56
4	2.18	49.92	2.22	117.71
5	1.82	50.21	2.15	117.51
6	1.62	64.57	2.30	73.17
7	1.76	64.41	1.76	73.73
8	2.27	64.02	2.18	73.32
9	2.86	63.54	2.38	73.32
10	1.61	63.00	1.58	132.56
11	1.21	63.32	1.38	132.69
12	1.38	63.17	1.35	132.76
13	0.73	63.70	1.18	132.82
14	1.03	64.94	0.86	74.59
15	1.87	64.26	1.09	74.44
16	−0.17	64.34	−0.20	134.17
17	0.00	64.21	0.00	133.99
18	0.42	63.91	0.59	133.59
19	0.43	63.87	0.15	134.00
20	1.94	64.18	0.87	74.79
21	0.16	64.02	−0.64	134.51
22	0.24	63.97	−0.54	134.63
23	1.75	64.26	−0.12	75.99
24	1.76	51.11	0.29	143.22
25	1.35	51.44	0.11	143.49
26	2.45	50.64	1.53	141.99
27	3.23	50.07	2.43	141.19
28	2.17	50.82	0.84	142.80
29	3.43	49.92	2.63	141.20

*Regions identified in Table 1 and Fig. 1.

†Consumption in carcass weight equivalent. Beef column aggregates beef and veal.

CONCLUSIONS AND IMPLICATIONS

The analysis provides a basis for examining procurement and distribution patterns for livestock and meat and for evaluating existing locations of slaughter activity:

- The solutions suggest potential procurement sources for livestock or meat products and outlets for livestock and meat under existing production, slaughter, and consumption conditions.
- Major competitors in procurement and distribution operations are identified and the competitive positions of different regions quantified by value differentials between regions.
- Adjustments in slaughter activity and location are suggested by optimum shipment patterns under existing market conditions. For example, shipment patterns revealing regional exports of live animals and imports of meat to meet local consumption requirements suggest a strong potential for expanded slaughter activity.
- Alternative as well as optimum procurement and distribution sources are identified and the estimated cost of non-optimum shipments is disclosed.
- Projections of 1975 regional production and consumption levels suggest potential changes in slaughter location and shipment patterns for the future.

Although the analysis provides helpful and useful information in identifying these distribution relationships, certain limitations are inherent in both the procedures and results:

1. The analysis assumes that each product is homogeneous, while in fact there are significant differences in both beef and pork products.

2. Relatively large geographic areas were included in each region. Each part of a region necessarily is assumed to possess the net surplus or deficit characteristics of the region as a whole. In recognition of this problem, Ohio was divided into two smaller regions to avoid errors of overgeneralization as much as practicable. Regions surrounding Ohio generally were limited to single states so the competitive position of the Ohio beef and pork industries could be more clearly identified in relation to these nearby competing regions.

3. Optimum shipment patterns also were generalized in respect to time, since annual data were used. However, seasonal changes typically occur in optimum shipment patterns and in the net surplus or deficit position of individual regions. These seasonal changes are not recognized in the analysis.

4. Shipment patterns obtained in this analysis, and implications of net results, have their basis in transportation costs between net surplus and net deficit regions for cattle, calves, hogs, beef, veal, and pork. Although transfer costs are a major consideration in efficient procurement and distribution of livestock and meat, other factors are considered in determining processing locations and movement patterns. The results of the analysis cannot be applied without regard to these other considerations.[26]

5. Data limitations frequently prevent transportation and spatial equilibrium model techniques from reaching their full potential. Many estimates of actual circumstances are employed. Even though the estimates are applied carefully, the data remain generalizations of complex individual components. For example, since beef production data needed for this analysis were not available in published form, estimates were necessary and were developed by adjusting published data as described in Appendix C. Regional demands also were estimated from functional relationships that do not specify regional price-quantity relationships precisely. Transportation costs further represent estimated relationships.

However, much of the data necessarily would be estimated by management in generating plans and decisions. So, in this context, this type of analysis can be an extremely useful and powerful tool for generalizing the nature, source, and implications of anticipated adjustments and changes.

Inplications of 1975 Projections

The projections and solutions for 1975 must necessarily be viewed as conditions and relationships that would exist under the set of assumptions employed and not as specific forecasts of 1975 conditions. However, the assumptions were employed with the judgment that they should provide a realistic and useful basis for analysis.

Indexes of regional changes in production-slaughter, consumption, and income appear in Table 22. Regional levels of production and slaughter relative to regional consumption levels are presented in Table 23. The projected changes in cattle and hog production, beef and pork consumption, population, and income suggest broad changes that may occur in the beef and pork industries by 1975.

Projected per capita consumption levels for beef and pork, projected levels of population and income, and assumed levels of imports of beef and pork all indicate a substantial increase in U. S. beef production by 1975 and a moderate increase in pork production. Under consumption

[26]For example, the quality of hogs available for slaughter, the availability of acceptable labor and utilities, and whether slaughter supplies are available throughout the year.

TABLE 22.—Index of Pork Production, Beef and Veal Production, Population and Per Capita Disposable Income, 29 Regions, United States, 1975 as a Percent of 1962* (1962 = 100).

Region	State	Pork Production†	Beef Production†	Population	Per Capita Disposable Income
1	Me., Vt., N.H., Mass., Conn., R.I.	86	105	118	135
2	N.Y. (N.Y.C. excluded)	95	99	110	126
3	N.J., N.Y.C., Phila.	95	116	120	138
4	Md., Del., D.C.	92	122	138	142
5	Pa. (Phila. excluded)	87	108	119	131
6	Virginia	101	164	116	138
7	West Virginia	87	153	85	136
8	N.C., S.C., Ga.	124	176	108	138
9	Florida	92	175	168	136
10	Eastern Ohio	103	127	126	133
11	Western Ohio	97	147	126	132
12	Michigan	102	134	129	131
13	Indiana	112	107	125	135
14	Kentucky, Tenn.	123	157	102	137
15	Ala., Mississippi	100	170	99	142
16	Minnesota, Wisconsin	109	149	123	132
17	Iowa	112	149	104	136
18	Illinois	123	142	127	132
19	Missouri	112	143	114	142
20	Ark., La.	58	165	111	147
21	N. Dakota, S. Dakota	112	157	97	114
22	Nebraska, Kansas	106	150	106	128
23	Oklahoma, Texas	57	159	121	136
24	Mont., Idaho, Wyo.	84	151	112	124
25	Colorado	76	158	132	129
26	N. Mexico, Arizona	119	173	158	135
27	Washington, Oregon	108	185	119	127
28	Nevada, Utah	99	152	130	131
29	California	60	173	146	133
	United States	110	151	122	134

*Slaughter comparisons are not included since the 1962 regional distribution of slaughter was assumed for 1975. Therefore, slaughter in all regions would increase from 1962 to 1975 at the same rate as national production of pork, beef and veal, i. e. 10 percent for hogs and 51 percent for cattle and calves.

†Based on projected production changes reflecting consumption assumption II.
Source: Original data.

TABLE 23.—Index of Slaughter Hog Production and Hog Slaughter as a Percent of Pork Consumption, and Index of Slaughter Cattle and Calf Production and Cattle and Calf Slaughter, as a Percent of Beef and Veal Consumption, 29 Regions, United States, 1962 and 1975.

(Consumption = 100)

Region	Hogs				Cattle and Calves			
	Production		Slaughter		Production		Slaughter[1]	
	1962	1975	1962	1975	1962	1975	1962	1975
1	5	4	16	17	14	10	16	17
2	5	5	56	63	40	30	64	72
3	1	1	15	15	2	1	18	18
4	15	12	36	32	20	15	22	20
5	24	19	103	105	44	33	96	99
6	40	38	107	112	55	64	58	63
7	13	15	20	29	48	70	41	61
8	67	85	68	77	30	40	52	60
9	14	8	20	15	15	12	65	47
10	25	23	66	64	27	22	60	58
11	140	117	100	96	57	54	74	72
12	28	24	44	41	34	29	57	55
13	338	335	227	221	81	57	93	92
14	98	130	123	148	106	136	90	112
15	61	68	58	72	86	120	89	111
16	230	225	245	241	187	185	191	192
17	1,357	1,626	1,079	1,267	707	829	633	755
18	233	250	120	115	105	96	74	72
19	270	292	198	211	138	141	147	159
20	28	16	26	29	55	68	65	72
21	514	660	416	523	471	626	264	338
22	335	368	422	482	580	668	516	599
23	29	15	41	42	217	234	161	166
24	70	58	70	75	254	277	107	117
25	36	23	86	80	328	319	323	300
26	9	8	25	19	199	177	56	43
27	22	23	62	63	55	70	84	87
28	18	15	55	51	76	73	106	100
29	6	3	26	22	65	63	83	70

Source: Original data.

assumption II, U. S. beef production would increase 51 percent between 1962 and 1975 and pork production would increase 10 percent. Under consumption assumption I, beef production would increase 61 percent between 1962 and 1975 and pork production would increase 2.5 percent.[27]

Major surplus regions for beef in 1975 probably will be in the Western Corn Belt, the Southwest, and parts of the South Central States. Beef production was projected to increase more rapidly than consumption requirements in parts of the South Atlantic and South Central States, in the western part of the Corn Belt and in region 24 (Montana-Wyoming-Idaho). Most of the North Atlantic States, Florida, parts of the Eastern Corn Belt, Colorado, Arizona, and New Mexico are expected to show somewhat greater increases in consumption than in production. The Arizona-New Mexico region, however, would be a major surplus beef region despite a decrease in its ratio of production to consumption.

The surplus position in pork production of the Corn Belt is expected to be even greater by 1975, with most of the increase in national production expected to occur in that area. The regions composed of Illinois, Indiana, Iowa, Missouri, Minnesota-Wisconsin, and North and South Dakota were projected to show increases in hog production ranging from 9 to 23 percent between 1962 and 1975. Smaller increases were projected for Ohio, Michigan, and Kansas-Nebraska.

In the 1975 production-to-slaughter and slaughter-to-consumption solutions, the regional distribution of cattle, calf, and hog slaughter was assumed to be the same as the 1962 distribution. Thus, slaughter volume for pork in each region would increase by approximately 10 percent in absolute tonnage, since a 10 percent increase was projected in total U. S. hog production under consumption assumption II. Slaughter of cattle and calves in each region was implicitly assumed to increase 51 percent in tonnage between 1962 and 1975.

The trend appears to be continuing toward greater concentration of slaughter in areas of livestock production to achieve distribution economies by movement of carcass meat rather than live animals. Therefore, some further increases in the proportion of production-oriented slaughter seems likely. The assumption of 1962 regional distribution of slaughter in 1975 may overestimate 1975 slaughter activity in regions where

[27]The consumption assumptions represent conditions that appear possible based on information from other research studies but are not predictions of 1975 consumption levels. Both assumptions reflect expectations for rapid growth in aggregate beef demand but only a modest aggregate increase in pork demand.

livestock production is projected to decrease and may underestimate the increase in regions where large production increases are expected.

The greatest increase in population between 1962 and 1975 is projected in the Southeast, West, Eastern Corn Belt, Florida, and parts of the North Atlantic area. Percentage increases in per capita disposable income are expected to be fairly uniform for the different regions, although wide regional differences in absolute level of disposable income will continue.

Summary of Implications

The major implications of the analysis can be summarized as follows:

1. Optimum outlets for surplus supplies of live hogs in Western Ohio in 1962 were regions 4 (Maryland-Delaware-D.C.) and 5 (Pennsylvania).

2. The deficit in slaughter hogs in Eastern Ohio in 1962 was met in the optimum solution by imports from Illinois, with Indiana and Western Ohio competing supply sources.

3. In 1962, Indiana and Illinois were the largest shippers of live hogs to deficit regions in the East, with Western Ohio an additional shipper. Iowa and Missouri were major shippers of surplus hogs to deficit regions in the West and Southwest.

4. Under projected 1975 conditions, Illinois was the largest single shipper of live hogs to surplus slaughter regions, with most of these shipments moving east. Western Ohio and Indiana also shipped live hogs to deficit regions in the East, while Iowa was a heavy shipper to the West and Southwest.

5. Eastern Ohio was a net importer of carcass pork in 1962 and in 1975. Western Ohio slaughter and consumption were in balance in 1962 but the region imported carcass pork from Indiana in the 1975 solution and received shipments from region 16 (Minnesota-Wisconsin) in the optimum solution. Iowa and Indiana were the major shippers of carcass pork to eastern deficit regions, along with Pennsylvania, Virginia, Illinois, and the Minnesota-Wisconsin region. Major shippers of carcass pork to the West, Southwest, and Southeast were Iowa, Missouri, the Dakotas, and the Kansas-Nebraska region.

6. Western Ohio appears to be in a favorable position to expand hog slaughter in view of out-shipments of live hogs and in-shipments of carcass pork in both 1962 and 1975 solutions.

7. Increased hog slaughter is also expected in Illinois, Indiana, Iowa, Missouri, and North and South Dakota, with decreases likely in most Eastern and Western regions.

8. A further decline in hog slaughter in Eastern Ohio appears likely in view of the current and projected low level of production relative to slaughter and consumption, in view of the trend to increased slaughter activity in regions of production concentration.

9. The optimum sources for imports by which Western Ohio might augment its deficit supplies of slaughter cattle and calves in 1962 were regions 22 (Kansas-Nebraska) and 23 (Oklahoma-Texas), with Iowa, Illinois, Colorado, and Kentucky-Tennessee as competing sources.

10. The optimum source of imports for meeting Eastern Ohio's deficit of slaughter cattle and calves in 1962 was region 24 (Montana-Wyoming-Idaho), with Iowa, Illinois, and the Dakotas as alternate sources.

11. Major shippers of live cattle to eastern slaughter locations in both 1962 and 1975 were Iowa, Nebraska, Kansas and the Dakotas, plus a small volume from regions 23 (Oklahoma-Texas) and 24 (Montana-Wyoming-Idaho).

12. Deficit slaughter cattle supplies for Ohio in 1975 would come largely from Nebraska, Kansas, Arizona, and New Mexico, assuming the 1962 regional distribution of slaughter. Regions 21 (North and South Dakota), 18 (Illinois), 17 (Iowa), and 24 (Montana-Wyoming-Idaho) were competing supply sources.

13. A moderate increase in cattle slaughter activity in Western Ohio between 1962 and 1975 appears likely in view of projected increases in production in that region.

14. Conditions appear favorable for major increases in cattle slaughter between 1962 and 1975 in regions 17 (Iowa), 18 (Illinois), 21 (North and South Dakota), 22 (Kansas-Nebraska), 23 (Oklahoma-Texas), 24 (Montana-Wyoming-Idaho), and 26 (Arizona-New Mexico).

15. With hog slaughter assumed to be completely production-oriented in 1962 and 1975 (models not presented in this discussion), Western Ohio woud ship carcass pork to Pennsylvania or West Virginia in the optimum shipment pattern, with Virginia, New Jersey and region 4 (Maryland-Delaware-D.C.) as alternate outlets. Eastern Ohio would obtain carcass pork from Illinois but would have sources nearly as favorable in Western Ohio, Indiana, Iowa, and Minnesota-Wisconsin.

16. With cattle and calf slaughter completely production-oriented in 1962 and 1975 (models not presented in this discussion), Western Ohio would import beef from Missouri and Kansas-Nebraska, with Illinois and Iowa as competing sources. In 1975, the Kansas-Nebraska region

would be the only source under optimum shipment conditons, although Missouri and Iowa would be close alternatives. Eastern Ohio would receive beef from the Minnesota-Wisconsin and Kansas-Nebraska regions, with Illinois and Iowa as competing sources.

APPENDIX A

Multiproduct Spatial Equilibrium Model Procedure

The two-commodity multiproduct problem can be represented by a two-equation model which describes the functional demand relationships for the two commodities:

1. $Q_1 = a_1 - b_1X_1 + b_2X_2 + c_1X_3$
2. $Q_2 = a_2 - b_3X_2 + b_4X_1 + c_2X_3$

where:

Q_1 = U. S. average per capita consumption of product (1)
X_1 = U. S. average retail price of product (1)
X_2 = U. S. average retail price of product (2)
X_3 = U. S. average per capita disposable income

Regional demand equations are of the form:

3. $Q_{1i} = a_{1i} - b_1 (X_{o1} + d_{oi1}) + b_2(X_{o2} + d_{oi2}) + c_1X_{3i}$
4. $Q_{2i} = a_{2i} - b_3(X_{o2} + d_{oi2}) + b_4(X_{o1} + d_{oi1}) + c_2X_{3i}$

in which the variables are the same as in equations (1) and (2) except that they represent regional quantities.

Prices are expressed as a base region price plus regional value differentials. Regional price differentials for each product are estimated from prior transportation model solutions, leaving only the base region prices unknown.

Summation of the set of regional demand functions yields a two-equation model in two unknowns (X_{o1} and X_{o2}) which can be solved simultaneously. The solution provides the necessary data for simultaneous estimation of regional consumption of the products. With production, slaughter, or other data predetermined, surplus and deficit regions can be identified and the optimum distribution pattern for each product obtained from separate spatial equilibrium model solutions.

Obtaining an equilibrium solution to the model requires the same iterative process as employed for the single-commodity model. To fully reflect product interrelationships, each recomputation of base region prices must take into account price differential changes on both products included in the demand functions. Thus, reiteration can occur only after solutions are obtained for both products and after resulting price differentials have been examined. As with the single-commodity model,

the equilibrium solution is obtained when two successive solutions yield identical price differentials for a product.

The multiproduct procedure can be readily extended to more than two products. However, the determination of base region prices becomes more complex as more variables are included. The iterative process employed in reaching equilibrium solutions also becomes more involved when the recalculation of regional demands requires consideration of price differential changes on several products.

Other implications of the multiproduct procedure appear in accompanying appendixes relating to other aspects of the study.

APPENDIX B

Allocation of Ohio Cattle and Hog Production between Regions 10 and 11

County data comparable to published state data on livestock production and marketings is not available. Therefore, the state totals of hog and cattle production were allocated between regions 10 and 11 on the basis of their proportional shares of total cash receipts from sale of these types of livestock in 1962. To derive these proportional shares, published county data on cash receipts from the sale of cattle and calves were aggregated for each region. These quantities were expressed as a percent of the state total.[28] The same procedure was used to derive estimates of hog production for the two regions.

In 1962, region 10 (Eastern Ohio) accounted for 36 percent of total Ohio cash receipts from the sale of cattle and calves. Region 11 (Western Ohio) accounted for 64 percent. On this basis, 1962 production of cattle and calves for slaughter in region 10 was estimated at 263,397,000 pounds liveweight. Production in region 11 was estimated at 468,262,000 pounds liveweight.

Region 10 accounted for 18 percent of the cash receipts from the sale of hogs in Ohio in 1962, with 82 percent in region 11. Using these same proportions, 1962 production of hogs was estimated at 165,351,000 pounds liveweight in region 10 and 753,268,000 pounds in region 11.

Allocation of Ohio Cattle and Hog Slaughter between Regions 10 and 11

Total slaughter of cattle and calves in Ohio in 1962 was estimated from published data at 1,202,464,000 pounds liveweight. Total hog slaughter was estimated at 969,338,000 pounds liveweight. These quantities were allocated between regions 10 and 11 on the basis of statewide survey data obtained from Ohio meat packers and processors in 1961 operations.

[28]Smith, M. G et. al. 1963 Ohio Farm Income, 1962. Ohio Agricultural Experiment Station, in cooperation with SRS, U. S. Dept. of Agriculture. AE 352.

The data indicated that cattle and calf slaughter within the state in 1961 was almost evenly divided between the two regions. Counties included in region 10 accounted for an estimated 49.5 percent of the volume reported slaughtered and region 11 for 50.5 percent. These proportions were used to estimate the regional slaughter totals used in this analysis. Thus, 1962 slaughter of cattle and calves in region 10 was estimated at 595,220,000 pounds and region 11 slaughter was estimated at 607,244,000 pounds.

The survey data indicated that approximately 44.4 percent of the hog slaughter within Ohio in 1961 occurred in region 10, with 55.6 percent in region 11. These proportions yielded slaughter estimates for 1962 of 430,386,000 pounds in region 10 and 538,952,000 pounds in region 11.

APPENDIX C

Estimated Production of Slaughter Cattle and Calves

This procedure can be expressed in equation form as follows:

$P_{si} = M_{ti} - M_{nsi} + S_{fi}$

where:

P_{si} = Annual production (pounds liveweight) of cattle and calves for slaughter in region i

M_{ti} = Total annual marketings (pounds liveweight) of cattle and calves in region i

M_{nsi} = Total estimated marketings of non-slaughter cattle and calves in region i (pounds liveweight)

S_{fi} = Total farm slaughter of cattle and calves in region i (pounds liveweight)

Also:

$M_{nsi} = M_{tc} - S_{tc} \bullet C_{bi}$

where:

M_{tc} = Total annual marketings (pounds liveweight) of cattle and calves in the United States

S_{tc} = Total annual commercial slaughter (pounds liveweight) of cattle and calves in the United States

C_{bi} = Percent of U. S. total cows 2 years and older on farms January 1 of year t located in region i

Thus, $M_{tc} - S_{tc}$ is the difference between the U. S. total annual marketings (liveweight) of cattle and calves and the U. S. total annual commercial slaughter (liveweight) of cattle and calves. This is used as an estimate of U. S. total marketings of non-slaughter cattle and calves.

It is assumed that most marketings of dairy cattle for breeding or milk production purposes are interfarm sales and are therefore not reflected in published data on cattle and calf marketings. This implicitly assumes that the bulk of the non-slaughter cattle marketed consists of stocker and feeder cattle and calves. The percent in a particular region of the U. S. total January 1 inventory of beef cows 2 years and older for the year under investigation is used as a basis for estimating the number of non-slaughter cattle marketed in that region.

Data on regional marketings of cattle and calves (M_{ti}) is available directly from state data published by the U. S. Department of Agriculture. Estimates of non-slaughter cattle and calf marketings must be derived by the method outlined. However, U. S. total annual marketings of cattle and calves (M_{tc}) and U. S. total annual commercial slaughter of cattle and calves (S_{tc}) are available from published sources. The regional distribution of the January 1 beef cow inventory (C_{bi}) can be derived readily from published data.

Regional farm slaughter of cattle and calves (liveweight) was estimated by multiplying regional data on number of cattle and calves slaughtered on farms by the U. S. average weights of cattle and calves slaughtered on farms. Both figures are available in published sources.

The procedure used to estimate regional marketings of non-slaughter cattle and calves results in estimates of total annual production of cattle and calves for slaughter (ΣP_{si}) that is equated with total U. S. slaughter of cattle and calves.

APPENDIX D

Determination of Regional Demand Functions for Beef and Pork

The regional demand functions were represented by the two-equation model:

1. $Q_{pi} = a_{1i} + b_1P_{pi} + b_2P_{bi} + c_1I_i$
2. $Q_{bi} = a_{2i} + b_3P_{bi} + b_4P_{pi} + c_2I_i$

where:

Q_{pi} = Average annual per capita consumption of pork in the ith region, retail pounds

Q_{bi} = Average annual per capita consumption of beef in the ith region, retail pounds

P_{pi} = Average retail price of pork in the ith region, cents per pound

P_{bi} = Average retail price of beef (including veal) in the ith region, cents per pound

I_i = Average annual per capita disposable income in the ith region, current dollars

Ratios of regional consumption of beef, veal, and pork to U. S. consumption were used to compute a-values (vertical intercepts) for the regional demand equations. Vertical intercepts computed for the national demand functions were used as a base. Regional a-values were computed to reflect a relationship to the national a-value (adjusted for income differences) comparable to the ratio of regional to national consumption of beef, veal, and pork appearing in the 1955 Household Food Consumption Survey.

Utilizing the components of both the national demand functions and regional demand functions, the desired relationship between regional and national a-values was obtained as follows:

$$a_i = \frac{M_i(a + b_pP_p + b_bP_b + cI)}{M} - (b_pP_p + b_bP_b + cI_i)$$

or

$$M_i(a + b_pP_p + b_bP_b + cI) = M(a_i + b_pP_p + b_bP_b + cI_i)$$

where:

M = Average per capita consumption of pork (or beef and veal) in one week, spring 1955, United States

M_i = Average per capita consumption of pork (or beef and veal) in one week, spring 1955, ith region

a = Constant value from appropriate national demand function

a_i = Constant value for particular meat in the ith region

P_p and P_b = U. S. average retail price for pork and beef for 1959-1962

I = Average disposable income per capita in the United States, 1959-1962

I_i = Average disposable income per capita in the ith region, 1959-1962

Prices of beef and pork were assumed constant in all regions. However, the effect of income differences on regional consumption patterns was accounted for by employing regional per capita income data in the computations. These variations in the regional a-values were considered to represent differences in consumption levels for pork, beef, and veal due primarily to consumer preference factors.

The regional prices for beef and pork, P_{pi} and P_{bi}, are composed of two separate elements. Thus, $P_{pi} = P_{po} + d_{oip}$ and $P_{bi} = P_{bo} + d_{oib}$ where P_{po} and P_{bo} are retail prices in a specified base region and d_{oip} and d_{oib} represent the respective price differentials on beef and pork between the base region and the ith region.

The price differentials, d_{oip} and d_{oib}, are estimated initially from transportation model solutions for the products and regions involved. In the spatial equilibrium analysis, each iteration yields a new set of price differentials until the equilibrium solution is obtained. The equilibrium solution is identified when two successive iterations yield identical price differentials.

Base region prices are derived algebraically by a process of aggregating known values in the regional demand functions. In the regional demand functions, $(P_{po} + d_{oip})$ is substituted for P_{pi} and $(P_{bo} + d_{oib})$ for P_{bi}. This yields a set of regional demand functions of the form:

1. $Q_{pi} = a_{1i} + b_1(P_{po} + d_{oip}) + b_2(P_{bo} + d_{oib}) + c_1 I_i$
2. $Q_{bi} = a_{2i} + b_3(P_{bo} + d_{oib}) + b_4(P_{po} + d_{oip}) + c_2 I_i$

The summation of these regional demand functions yields the following two equation models:

1. $$\sum_{i=1}^{29} P_i Q_{pi} = \sum_{i=1}^{29} a_{1i} P_i + b_1 \sum_{i=1}^{29} P_i P_{po} + b_1 \sum_{i=1}^{29} P_i d_{oip} + b_2 \sum_{i=1}^{29} P_i P_{bo} + b_2 \sum_{i=1}^{29} P_i d_{oib} + c_1 \sum_{i=1}^{29} P_i I_i$$

2. $$\sum_{i=1}^{29} P_i Q_{bi} = \sum_{i=1}^{29} a_{2i} P_i + b_3 \sum_{i=1}^{29} P_i P_{bo} + b_3 \sum_{i=1}^{29} P_i d_{oib} + b_4 \sum_{i=1}^{29} P_i P_{po} + b_4 \sum_{i=1}^{29} P_i d_{oip} + c_2 \sum_{i=1}^{29} P_i I_i$$

where P_i represents human population in the ith region and $\sum P_i Q_{pi}$ and $\sum P_i Q_{bi}$ are assumed to be equal to U. S. total population times U. S. average per capita consumption of pork and beef (including veal).

Price differentials for the equations are obtained from a prior transportation model solution. All other data and coefficients except P_{po} and P_{bo} are available from published sources or have been previously determined. The solution of this system of two equations in two unknowns is the set of values, P_{po} and P_{bo}.

In reaching an equilibrium solution, each iteration of the data yields a somewhat different set of price differentials for both products until the equilibrium point is reached. After each iteration, any changes in price differentials must be reincorporated in the model, revised base region prices computed, and regional demands redetermined. Two successive iterations yielding identical sets of price differentials for both beef and pork indicate that the solution has provided equilibrium quantities and prices for both products and the optimum distribution pattern for the amounts involved in interregional trade.